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OBSERVATIONS ON THE DETERMINATION OF HYDROGEN-ION CONCENTRATION OF DOUGH, AND ON THE RELATION OF HYDROGEN-ION CONCENTRATION TO FLOUR GRADE

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In an earlier paper (Halton & Fisher, 1928) we reported that we found gold electrodes to give consistent and reliable results when used in conjunction with the quinhydrone electrode for measuring hydrogen-ion concentrations in water extracts of flour. Such electrodes have been tested on many occasions by using them for determining hydrogen-ion concentrations in standard buffer solutions. Even when used for considerable periods without cleaning they have not failed to give correct and reproducible readings and cleaning with chromic acid or by heating in an alcohol flame has not affected the reliability of the electrodes. Careful attention, however, has been necessary to one point, the importance of which does not appear to have been fully appreciated by all workers; the development of cracks, however minute, in the glass holders is very liable to cause serious errors. It has been found necessary to exercise the same care when dealing with doughs as with flour suspensions as a small unobserved crack may vitiate the determination.

When a gold electrode is placed in a flour-water-quinhydrone mixture the E.M.F. set up usually shows a drift with time. With some flours this is so small that it can be detected only by taking readings over a considerable period, while with others it is quite large. That this drift may be due to the interaction of some flour constituent and quinhydrone, but certainly not to changes taking place in the flour suspension itself in the absence of quinhydrone, is shown by the results given in Table I obtained by making a large flour-water suspension, taking samples of it immediately after shaking and at fifteen minute intervals, and, after adding quinhydrone, determining their H-ion concentrations after stated times.

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The figures given in Table I show that concordant pH figures cannot always be obtained immediately after adding quinhydrone to a flour-water suspension. Readings taken a few minutes after the addition of the quinhydrone are steady and reproducible, within the limits of experimental error, no matter whether the quinhydrone is

TABLE I
RELATION BETWEEN APPARENT pH OF A FLOUR-WATER SUSPENSION AND (a) AGE OF SUSPENSION, AND (b) TIME ELAPSING BETWEEN ADDING QUINHYDRONE AND TAKING pH READING

Time from making suspension to taking sample and adding quinhydrone	pH readings at varying times between adding quinhydrone and taking pH readings			
	0 mins.	15 mins.	30 mins.	45 mins.
0 mins.	5.99	5.83	5.78	5.75
15 mins.	6.13	5.86	5.79	6.75
30 mins.	5.92	5.84	5.79	5.75
45 mins.	6.09	5.84	5.78	—
60 mins.	6.08	5.86	—	—

added as soon as the suspension is made or, say, an hour later. Similar tests with doughs showed that, as with flour-water suspensions, no decrease in pH took place before the addition of the quinhydrone. An examination of Table I also shows that there was a comparatively large drift of 0.07 in pH between the fifteen and thirty minute readings, and a further drift of 0.03 from thirty to forty-five minutes. These are exceptionally large even for flour-water mixtures and are much greater than those occurring in doughs. Measurements on doughs made from a series of flours milled from Manitoba, Hard Winter, Karachi, Russian and English Wheats, and mixed grists, showed in the majority of cases a drift of about 0.01 in pH between the fifteen and thirty minute readings. Because of such occasional drifts, however, it becomes necessary to allow a definite time to elapse between adding the quinhydrone and making a measurement. Fifteen minutes has been found to be a convenient period as with small doughs this is long enough for temperature equilibrium to be reached when they are placed in the thermostat. As stated in our earlier paper such drifts have not been observed to take place in filtered or centrifuged flour extracts or in decantates from suspensions that have been allowed to settle. In the conventional methods of measuring hydrogen-ion concentration of such extracts by means of gold-quinhydrone electrodes drifts are not therefore a source of error.¹

¹Sorg (1930) stated that "Halton and Fisher (1928) have noticed a drift of potential in using the quinhydrone electrode. It will be seen . . . that no such drift occurs." This statement is based on an incorrect reading of our earlier (1928) paper. In working with aqueous *extracts*—centrifuged, decanted or filtered—of flour we found drifts of potential to occur only with platinum, not with gold, and stated "gold electrodes were then tried with completely satisfactory results." Sorg's discoveries of drifts with platinum and none with gold are therefore confirmatory of our earlier results. As stated above, however, drifts of potential may occur in some cases (but not with all flours) even with gold-quinhydrone electrodes in flour suspensions.

In our earlier attempts to use gold-quinhydrone electrodes with doughs erratic results were obtained. For example, a series of determinations on a number of replicate doughs made without yeast from the same flour using exactly the same technique in each case gave the following pH readings: 5.57, 5.69, 5.69, 5.65, 5.69, 5.60, 5.57, 5.70, 5.49—a range of 0.21. Such differences were not due to temperature variations as the doughs were made and maintained at the same temperature. The doughs were kept in test tubes in a thermostat and the measurements were made on the doughs without removal from the bath. Thermometers kept in the doughs indicated that all were at the same temperature, viz., that of the thermostat (25° C.). Slight differences in the proportions of water or of quinhydrone were found not to alter the hydrogen-ion concentration, and cleaning the electrodes in chromic acid or by heating did not remove the trouble. When, however, the electrodes were freshly plated with gold, and after plating were well washed with running water and “flamed” in an alcohol flame, much more concordant results were obtained. A series of determinations made on replicate doughs after such treatment, resulted in the following pH readings: 5.71, 5.71, 5.69, 5.69, 5.69, 5.71, 5.72, 5.71, 5.70—a range of only 0.03. Gold blades, gold wire and gold plated platinum have been used as electrodes for work with doughs but, with all, frequent replating with gold has been found to be necessary. Between determinations the electrodes should be well washed to remove any tiny particles of adhering dough, and after drying should be “flamed.” At the commencement of a series of tests, it is advisable after preparing a number of electrodes to place them all in the same small well-mixed dough and select for use those which give identical pH readings after about fifteen minutes. It is sometimes found that freshly plated electrodes take longer to attain equilibrium with a dough than after once using. After being used for a series of determinations it is advisable to remove the gold deposit by electrolysis and replating from cyanide solution, as electrodes so treated appear to give less trouble than those replated on top of the old gold deposit.

In preparing a dough for a determination, the quinhydrone can either be mixed with the flour before doughing up with the water, or rubbed in afterwards. A satisfactory quantity of quinhydrone to use is 1% of the weight of the flour. With some doughs a wide variation in the quantity of quinhydrone has no effect on the pH figure obtained, while with others the E.M.F. set-up is influenced by the quantity

A similar drift, but in the opposite direction, said to be due to the reduction of manganese dioxide to manganous hydroxide by hydroquinone, was noticed in some soil suspensions by Heintze and Crowther (1929).

When actual flour suspensions are dealt with, as in the work discussed later in this paper, the possibility of such drifts must be taken into account; e.g., pH measurements taken after two or three and after fifteen minutes after the addition of the quinhydrone will indicate the presence or the magnitude of the drifts.

used, an effect due possibly to the interaction of some constituent of the flour with quinhydrone. This point is illustrated by the figures given in Table II.

TABLE II
RELATION BETWEEN APPARENT pH OF A DOUGH AND THE AMOUNT OF
QUINHYDRONE USED

Quinhydrone used as percentage of flour	Apparent pH	
	Flour A	Flour B
1.0	5.67	5.68
2.0	5.68	5.66
3.0	5.69	5.63
4.0	5.68	5.61
5.0	5.69	—

The problem of determining with reasonable accuracy the hydrogen-ion concentration of a dough is one of great theoretical interest and is a necessary preliminary to extending our almost negligible knowledge of flour reaction. Our earlier reported work (1928) indicated that the quinhydrone electrode gave erratic and discordant results with doughs. Further work, however, enabled us to overcome these difficulties, and we have found that with the precautions discussed above gold electrodes can be used with considerable accuracy for the determination of the hydrogen-ion concentration of small bits of dough with which quinhydrone has been incorporated. Since this work was commenced a similar procedure has been introduced by Whittier and Grewe (1929) who have called it the ball quinhydrone method. We propose to adopt this short convenient designation. Although it is not possible, for the reasons already stated, to compare the results of the ball quinhydrone method on doughs with those of the ordinary quinhydrone electrode method on flour-water mixtures, we have on innumerable occasions compared the ordinary gold-quinhydrone and hydrogen electrode methods on the same flour extracts. Using the precautions outlined in this and our earlier paper we have obtained invariably excellent agreement and appear to have eliminated the discrepancies previously reported when platinum electrodes were used and which Whittier and Grewe noticed between the Bailey hydrogen electrode and their capillary quinhydrone electrode. We agree with Whittier and Grewe, however, that pH values obtained on doughs by the ball quinhydrone method are a closer approach to a true measurement of the hydrogen-ion concentration (or acid-base equilibrium) existing in flours than are the values obtained by other methods.

In our earlier paper (1928) we showed that the greater the concentration of flour in a flour-water mixture the greater was the hydrogen-

ion concentration, that is the smaller, numerically, was the pH of the mixture. We also showed that this change in pH with changing flour concentration was greater with low-grade than with patent flours. The results pointed to the unexpected conclusion that a series of doughs made from a series of "divides" (i.e., flours of different grades) from the same flour stream (made from a single type of wheat)² show strikingly small differences in hydrogen-ion concentration even if they do not turn out to be substantially the same. When the determinations are made in the conventional manner, using flour-water ratios of 1 : 10, the hydrogen-ion concentration of such divides may be, and usually are, widely different.

In order to examine further the relation of flour grade to the hydrogen-ion concentration of doughs and flour-water suspensions the following series of flours were obtained from a mill during the milling of some all-English (non-Yeoman) wheat:

Flour	Ash content
33% top patent flour	.440%
C roll flour	.450
1st break flour	.457
2nd break flour	.495
Alphega flour from first three breaks combined	.507
3rd break flour	.522
66% bottom divide (bakers' grade)	.550
4th break flour	.670
L roll flour	.810

Each of these flours was examined over a range of concentration of one part flour and ten parts water to one part flour to half part water. In each determination the flour, water and quinhydrone were mixed together, an electrode inserted and the pH determined after the whole had remained in a water bath at 25° C. for fifteen minutes.

These measurements, given in Table III, show that the pH of the doughs from these various flours, although not identical, fell within a range of 0.13 pH compared with a range of 0.48 pH for the 1 : 10 flour-water mixtures. An examination of Table III and Figure 1 reveals that in a general way the magnitude of the change in pH with flour concentration is in the same order as the ash contents; i.e., the lower grade flours with the highest ash contents show the greater changes in pH as the water content of the mixture is increased. The flours fall into four well defined groups:

- (1) The flours from fourth break and L roll, with very high ash

² This proviso is important. It is well known to millers that in milling a mixture, say, of soft English, Manitoba and Durum wheats, the English wheat tends to concentrate at the head and the Durum wheat at the tail of the mill. The high and low grade flours from such a mixture would contain different proportions of the constituent wheats and might therefore differ in other characters, e.g., in hydrogen-ion concentration.

TABLE III

RELATION BETWEEN THE pH'S OF A SERIES OF DIVIDES OF ALL-ENGLISH FLOUR AND THE AMOUNT OF WATER USED IN MAKING THE SUSPENSIONS

Flour	Ratio flour-water						
	1:10	1:6	1:4	1:2.5	1:2	1:1.5	1:1
	pH's						
33% top patent	5.88	5.87	5.88	5.86	—	5.84	5.83
C roll	5.85	5.85	5.85	5.84	—	5.84	—
1st break	6.05	6.00	—	—	5.90	—	—
2nd break	5.96	5.96	—	—	5.88	—	—
Alphega from first							
three breaks	5.97	5.96	—	—	5.89	—	—
3rd break	6.13	6.12	—	—	6.02	—	—
66% bottom	6.15	6.12	6.08	5.98	—	5.92	5.88
4th break	6.33	6.28	—	—	6.11	—	—
L roll	6.32	6.26	6.20	6.11	—	6.04	5.96

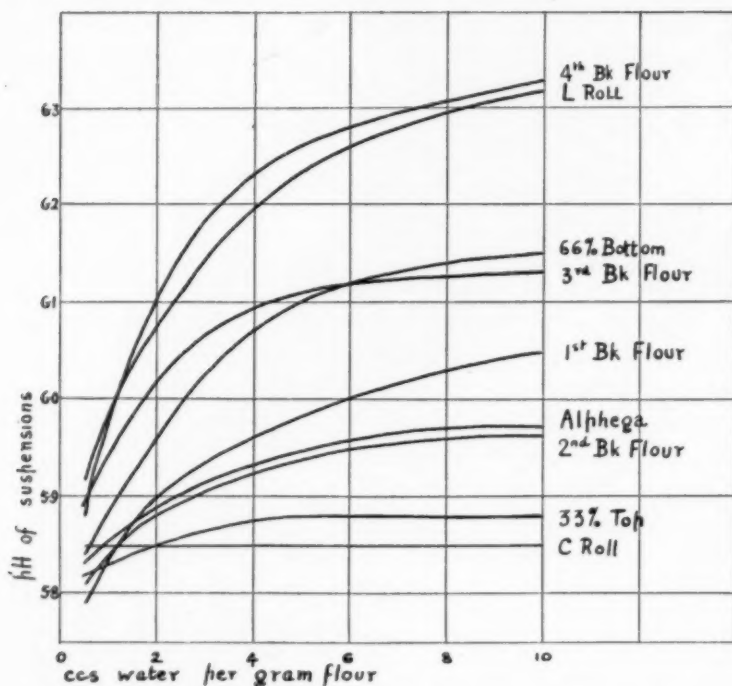


Fig. 1. Effect of flour concentration on the pH of flour-water suspensions.

content, change most in pH with varying water content and their pH-concentration curves are closely similar and close together.

(2) The 66% bottom divide and third break flours behave similarly. They are well below the first group in ash content and their curves are well below those of the first group.

(3) The combined Alphega flours and the second break flour form a separate group, closely similar in ash content and in curves.

(4) The top patent and C-roll flours are similar.

The first break flour is anomalous. From its ash content it should associate with the patent and C-roll flours. Actually its pH, i.e., the pH of its dough, is the lowest (most acid reaction) of the lot and is nearest the patent; its curve, however, resembles that of the third break flour. This is interesting because, as millers are aware, the first break flour is anomalous in other ways.

It is not possible at present to account for this striking influence of water on the pH of lower and low grade flours. It is not a simple direct dilution effect as that phrase is understood by chemists because (a) it does not occur at all with C-roll flour, and to only a slight degree with the patent flour, and (b) the effect is altogether too great; phosphate buffer solutions, for example, change only slightly in pH over a similar range of dilutions.

It does not appear to be directly due to the ash although its magnitude is correlated with ash content. About 50% of the mineral matter of flour consists of mono- and di-potassium phosphates and, if these are mainly responsible for the effects observed, it should be possible by suitable additions of these two phosphates to C-roll flour to change the C-roll curve to an L-roll curve. After a number of trials this was done but (cf. Table IV and Figure 2) the amount of

TABLE IV
EFFECT OF ADDITION OF PHOSPHATE MIXTURE ON THE pH-CONCENTRATION CURVES OF FLOUR SUSPENSIONS

Phosphate mixture added = 1% KH_2PO_4 plus 0.5% K_2HPO_4				
cc. water per gram flour	10.0	6.0	2.0	0.5
pH	6.31	6.28	6.14	5.85
Phosphate added = 0.24% KH_2PO_4 plus 0.12% K_2HPO_4				
cc. water per gram flour	10.0			0.5
pH	6.14			5.83
Phosphate added = 0.19% KH_2PO_4 plus 0.19% K_2HPO_4				
cc. water per gram flour	10.0			0.5
pH	6.31			6.04

phosphate mixture required (1.5%) was four or five times the difference in ash content, or eight or ten times the difference in phosphate content of C-roll and L-roll flours. An addition of phosphate comparable with the difference in ash content of C- and L-roll flours, e.g., 0.3 to 0.4%, produced much smaller effects. Further, a more alkaline phosphate mixture added to C-roll flour produced a different type of curve.

The phenomena cannot be entirely explained by assuming the progressive hydrolysis of some constituent (or constituents) appar-

ently absent from short patent flour (C-roll) but present in lower grade flours in amounts roughly proportional to the ash contents of the flour. Such progressive hydrolysis, if occurring, might afford an explanation of the effect of dilution in raising the pH of flour suspensions; it could not explain the observed fact that the H-ion concentration of the flour is different from (lower than) that of the supernatant liquid (Halton and Fisher, 1928).

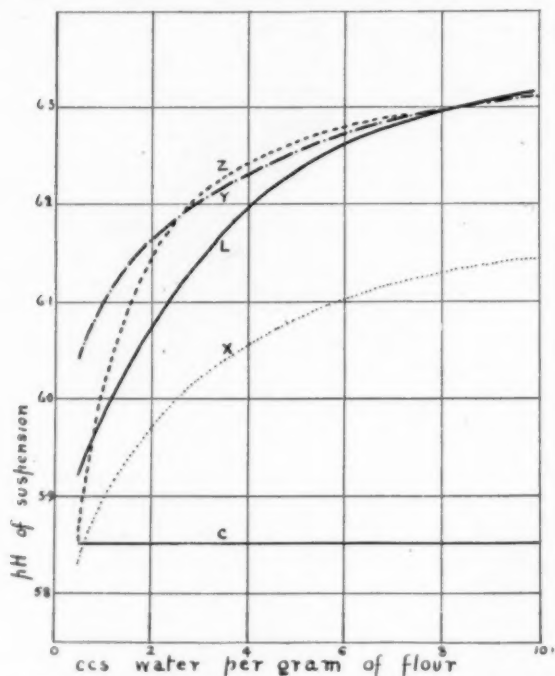


Fig. 2. Effect of phosphate on the pH of water suspensions of a short patent flour (C. Roll).

Curve C. C roll flour.
 Curve X. C roll flour plus 0.24% KH_2PO_4 plus 0.12% K_2HPO_4 .
 Curve Y. C roll flour plus 0.19% KH_2PO_4 plus 0.19% K_2HPO_4 .
 Curve Z. C roll flour plus 1.0% KH_2PO_4 plus 0.5% K_2HPO_4 .
 Curve L. L roll flour.

The results certainly suggest the presence in lower grade flours of substances which appear to be absent from short patent flour (pure endosperm). The investigation is being continued from this point of view as it may throw some light on the relation between quality and grade of flour.

It appears to us that the observed difference in the H-ion concentration between the two phases of a flour-water suspension can only be explained by the assumption of an adsorption of hydrogen-ions by the flour, an adsorption of such a character that the adsorbed hydrogen-ions can exert an E.M.F. in the liquid immediately surrounding the

flour in consequence of which their presence can be detected potentiometrically. Such adsorption equilibria are known in other systems. The phenomenon is being investigated further.

Summary

The gold-quinhydrone electrode has been used successfully for determining the H-ion concentration of dough. The precautions necessary for accuracy have been pointed out.

The H-ion concentrations have been determined of a series of nine divides from a flour stream of all-English (non-Yeoman) flour over a range of concentration of one part of flour and ten parts of water to one part of flour and one half part of water (or dough). The results show that the pH's of the doughs of the various divides are fairly similar whereas those of the 1 : 10 flour-water mixtures are widely different.

The effect of water in increasing the pH is nil with a very short patent flour but increases rapidly as flour grade decreases (or as ash content increases).

The results suggest that the phenomenon is not due directly to the mineral content of flour, although it is correlated with ash content, but that some hydrolysable constituent is present in low grade flours which is absent from short patents (pure endosperm).

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TESTING WHEAT VARIETIES FOR MILLING AND BAKING QUALITY¹

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(Read at the Convention, May, 1931)

Introduction

That new wheat varieties are not demanded by bakers, nor millers, but by wheat producers, has been pointed out by Sherwood (1930). For this reason the agronomic qualities of any new wheat variety are of first importance. In the first place the new variety must be more profitable to the producer than any of the older varieties. This means that it must be a good yielder. To be a good yielder of course involves adaptation to the climatic and soil conditions where it is grown. For a bread wheat, either winter or spring grown, resistance to the dry weather conditions of the plains area, or to the high temperatures which are likely to occur during the later period of growth, are of importance. The new variety must have a stiff straw so that it may be grown on soils fairly rich in nitrogen, making possible high yields and wheat of high protein content. The new variety must have properties which adapt it to the newer methods of harvesting. The new variety must also be resistant to the prevailing wheat diseases. The problems of producing a new wheat variety which shall meet all these conditions would be sufficiently difficult without introducing the additional requirements that the new wheat variety must have satisfactory milling and baking qualities; at least as good as those of the older and accepted varieties. However, these additional conditions must be met, and it becomes the task of cereal chemists who are connected with experiment station laboratories to evaluate the new wheat varieties from the milling and baking standpoint.

This problem is further complicated by the fact that soil, season, and weather conditions prevailing during the growing season and even after harvest, also exert an influence on milling and baking properties in addition to genetic factors. It is sometimes very difficult, if not impossible, to know how much of the quality measurements shall be attributed to the genetic factors and how much to those of growth and post ripening conditions. Because of the difficulty of making this differentiation it is necessary to grow a new variety for a series of

¹ Contribution No. 41, Department of Milling Industry.

years under various soil and climatic conditions. Variations in harvesting conditions must be avoided as much as possible, but often the people in charge of this part of the work do not realize how much the weather conditions during harvest may affect the quality.

Characteristics of a Good Milling Wheat

Good milling characteristics must include fairly easy separation of bran from endosperm so as to produce a good yield of flour of low ash content. The endosperm should not be so hard that it requires an undue amount of power to reduce it to fine flour. The endosperm also should have a minimum of the yellow coloring matter; at least coloring matter should not be in excess of the amount which can be removed by bleaching without injury to the flour. Test weight per bushel is of importance. Test weight and flour yield are closely correlated, but it should be pointed out that test weight is so much influenced by soil and season that it is often very difficult to tell how much is due to genetic factors. That test weight may be influenced by genetic factors is shown by the fact that Blackhull has a significantly higher test weight than Turkey or Kanred when these three wheats are grown side by side for a series of years, and in various places. Salmon, Swanson, and Laude (1927) showed that the average test weights in 242 trials in Kansas over a series of five years were Blackhull 60.4; Turkey 58.2; Kanred 57.1; showing a difference of two to three pounds in favor of Blackhull, but this higher test weight did not produce a proportionately higher yield of flour, as the flour yields of the three varieties were very nearly the same.

The Experimental Milling Test and Its Limitations

Milling is a mechanical operation and the milling test is usually made on a small experimental mill. If the purpose is merely to produce a small quantity of flour on which to make further tests, then the problem is comparatively simple, but if it is desired to know the potential flour yielding capacity of the wheat, then the problem is more complicated. The average wheat kernel consists of approximately 14.5% bran; 1.5% germ; and 84% endosperm. In average commercial milling there is obtained 70-72% flour and 28-30% feed. This means that about 12% of the endosperm goes into the feed. There is no known method of milling which will separate all the endosperm from the bran and germ.

In making experimental milling tests on wheat the operator tries to approximate the commercial product as near as possible. But where is the end point at which the operation should stop? If all wheats had the same test weight, then it might be best to mill until a

certain per cent of flour was obtained from each sample. The ash content of the flour would then be a fair indication of the cleanness of separation of bran from endosperm, and the results over a series of years on wheats grown in various places would show which wheat was easiest to mill. But as all wheats do not have the same test weight, milling to a certain per cent is not applicable.

While flour yield is correlated with test weight it is not a linear function of the same. If it were it would be possible to base the extraction on test weight. Suppose it was decided to use 1.2 times the test weight as the basis of the flour yield to be obtained in milling. A 60-pound wheat would then be milled to 72% flour, a figure not far from what is obtained in actual practice. However, for higher or lower test weight it would not give good agreement with what is obtained in actual practice. This can be seen from the figures in Table I which are computed on the assumption that an extraction should be made which would be equal to 1.2 times the test weight.

The general effect of this method would be to penalize the high test weight wheats and favor those of lower test weight. It might be possible to use a series of graduated factors. But how should they be graduated, and what should be the differential magnitude?

TABLE I

PERCENTAGES OF FLOUR WHICH WOULD BE OBTAINED IN MILLING TO AN EXTRACTION PREDETERMINED BY THE TEST WEIGHT TIMES THE FACTOR 1.2

Test weight	Per cent flour	Test weight	Per cent flour
Pounds		Pounds	
51	61.2	58	69.6
52	62.4	59	70.8
53	63.6	60	72.0
54	64.8	61	73.2
55	66.0	62	74.4
56	67.2	63	75.6
57	68.4		

Compared with other laboratory methods, very little work has been done on the best way of making milling tests on wheat. Have we conducted the experimental milling test in too mechanical a manner, too much dependent on the operator's skill? Is it possible to make the milling test mean more than it has in the past? Would it be possible to supplement the mechanical operation by some chemical tests on the end products? The ash test on flour may be used, but since the endosperms of different wheats vary, it is very difficult to know how much the ash test is influenced by the milling operation and how much by the variation of the non-combustible portion of the endosperm. The recent method developed for determining starch by

Herd and Kent-Jones (1931) might be helpful in determining the potential flour yield of wheat varieties by estimating the starch of both wheat and products. It seems that we need to put the milling test on a better scientific basis.

The Value of Chemical Methods for Determining Wheat Quality

Ever since chemical methods were applied to the testing of wheat, the chemists have looked for convenient chemical determinations which would evaluate wheat. Protein is the most widely used single test for evaluating bread wheat, but the protein content is so much influenced by growth conditions, that it is of very little value as a measure for comparing quality in different varieties. Whether some varieties have more ability to store protein than other varieties is not a settled question. That some varieties are more adapted to take better advantage of prevailing growth conditions is very apparent because they have been selected and bred for this very purpose.

The protein content of several common winter wheat varieties was determined in a series of cooperative tests with farmers conducted in various parts of Kansas by the Department of Agronomy. The protein content of three principal varieties is given in Table II. These figures are the averages from a large number of tests on various types of soil and since the time extends over five years the wheats were grown under a large variety of weather conditions. There is no question about the significance of the annual variation, but among varieties the differences are not any greater than they would be if all the samples had been grown from a lot of the same variety.

TABLE II
AVERAGE PER CENT OF PROTEIN IN WHEAT VARIETIES

Year	Kanred	Turkey	Blackhull
1923	12.5	12.2	12.5
1924	11.0	11.1	11.4
1925	12.8	12.5	12.4
1926	13.7	13.8	13.8
1927	12.8	12.7	12.5
Yearly average	12.5	12.4	12.5

The Baking Test as a Measure of the Quality of Bread Wheats

The baking test is generally regarded as the best measure of quality in a bread wheat. The best way of making this test is still an object of serious study. The baking test is apparently on surer ground when used in mill control than when used in evaluating varieties. In the former case the test is used mainly on flour from a fairly uniform wheat mixture and the purpose is to evaluate the flour for a class of

trade more or less known. In using the test to evaluate wheat varieties the problem is somewhat different. As a rule, many members of the milling and baking trades object to new varieties. They have objected in turn to Turkey, Kanred, Blackhull, as well as to other new wheats, and the originators of any new varieties may expect objections to their new creations if these are measurably different from the old. To satisfy both producers and consumers the plant breeder seeks to make his creations better than the old for the producer, and at the same time be similar in the milling and baking characteristics to the old and tested wheat varieties.

Because of this situation, the standards used in testing new varieties are based on the performance of the old varieties. For bread wheats Turkey is the generally accepted standard for hard winter wheat, and Marquis for hard spring wheat.

Choice of a Baking Test Procedure

What procedures in making baking tests will best evaluate characteristics due to genetic factors in contrast with those due to soil, climate, harvest conditions, and methods of milling? A baking test that will fulfill these conditions must give recurring characteristics in the baked loaf no matter in what year or where the wheat has been grown. At first thought it might seem that this is an impossibility. However, we have found that the resistance to mechanical action and the response to potassium bromate are characteristics largely determined by genetic factors. More work has been done in the baking laboratory, of the Kansas Agricultural Experiment Station, on the former than on the latter. The disconcerting fact is, that the resistance to mechanical action and the response to bromate point in opposite directions. That is, a variety which responds well to bromate seems to have poor resistance to mechanical action, and vice versa.

The baking test based on the resistance to mechanical action using the high speed dough mixer has been described by Swanson and Working (1926). The results obtained by this method on several important varieties were compared in 1929 by Swanson (1930) with the results obtained in a number of cereal laboratories where different methods were used. The ranking of four varieties by 17 cooperating chemists was as follows:

	First	Second	Third	Last
Tenmarq	12	2	1	2
Kanred or Turkey	1	10	5	2
Blackhull	3	4	5	2
Superhard	1	0	3	11 ²

² These numbers do not add up to 17 in each case because some wheats either were not ranked or several wheats were given the same value.

In our work it was found that when baking quality was measured by resistance to mechanical action, flours milled from Tenmarq, and Kanred or Turkey wheat varieties gave much better results than flours milled from either Blackhull or Superhard wheat varieties. This was found to be true regardless of soil or season. That different rankings and opposite conclusions as to quality were given by some chemists was due in part at least to their use of the bromate differential test.

Baking Tests on Wheats from the Crop of 1930

A similar series of tests as just described for the 1929 crop were made on wheats of the 1930 crop. For a number of years the Department of Agronomy has been conducting tests on several principal wheat varieties in different sections of the state. The wheats are grown in cooperation with farmers. This gives opportunity to test the wheats under actual farm conditions. A new variety is always grown in direct comparison with old and tested varieties.

From the bread wheats grown in 1930 composites were made representing the north and south halves of the hard red winter wheat belt of Kansas. The baking results differed in no essential manner with the wheats from either section.

The data in the following tables were selected from the results which were obtained on composite samples milled from samples of Turkey or Kanred, Tenmarq, Blackhull, and Superhard varieties of wheat.

Values for water absorption, protein content of wheat, and the ash content of the flours which were studied, are given in Table III.

TABLE III
WATER ABSORPTION, PROTEIN CONTENT OF WHEAT, AND ASH CONTENT
OF FLOUR

Variety	Water absorption of flour	Crude protein in wheat	Ash in flour
	P.ct.	P.ct.	P.ct.
Blackhull	63	12.1	0.46
Superhard	67	12.1	.49
Kanred	66	12.6	.49
Tenmarq	67	11.9	.48

Baking tests were made on these samples of flour by the mechanical modification method,³ the bromate method, and the three hour fermentation method.

From the data recorded in Table IV it is evident that opposite

³ The method used to test this will be designated mechanical modification. The baking test is made by mixing the dough in the Swanson (Swanson 1928) high speed dough mixer very severely for five minutes and then proofing without previous fermentation.

baking results were obtained when testing these flours by the mechanical modification method and by the bromate method. Using the mechanical modification method the varieties would be ranked, Tenmarq, Kanred, Blackhull, and Superhard. Using the bromate

TABLE IV
COMPARISON OF THE MECHANICAL MODIFICATION METHOD WITH THE RESPONSE TO BROMATE

Variety	Mechanical modification		2 mg. bromate per 100 gm. flour	
	Loaf volume	Texture	Loaf volume	Texture
	cc.	P.ct.	cc.	P.ct.
Blackhull	1765	89	2105	98
Superhard	1705	88	2030	99
Kanred	1896	96	2000	95
Tenmarq	1945	98	1960	96

method the ranking would be, Blackhull, Superhard, Kanred, and Tenmarq. This relative position is based on tests which have been repeated over and over again on flours from wheats grown in various parts of Kansas and other states. Whatever the merits or demerits of the method of mechanical modification³ may be, it does reveal characteristics due to genetic factors regardless of where the wheat is grown. The protein content has relatively little influence when this method is used. While we have not made many tests with the bromate method, it appears that this is also related to genetic factors. However, the results point in opposite directions, i.e., Blackhull is not able to stand mechanical action but *is* benefited by addition of bromate. Tenmarq, on the other hand, is able to withstand mechanical action but is injured by the addition of bromate.

Photographs of loaves produced by the mechanical modification procedure and the response to bromate test are shown in Figures 1 and 2. These photographs show quite definitely the opposite effects which obtain by the use of the two methods. The variety Blackhull and its relatives—Superhard and Early Blackhull—made better bread with the addition of bromate, while the variety Turkey and its relatives—Kanred and Tenmarq—gave poorer results.

Figures 3 and 4 illustrate the results which were obtained by two Kansas City chemists with flours milled from Blackhull, Kanred, and Tenmarq wheat. These chemists obtained some increase in loaf volume by the use of 1 milligram of potassium bromate per 100 grams of flour. Figure 4 shows rather small differences between varieties, while Figure 3 shows Blackhull to be distinctly the poorest and Tenmarq the best.

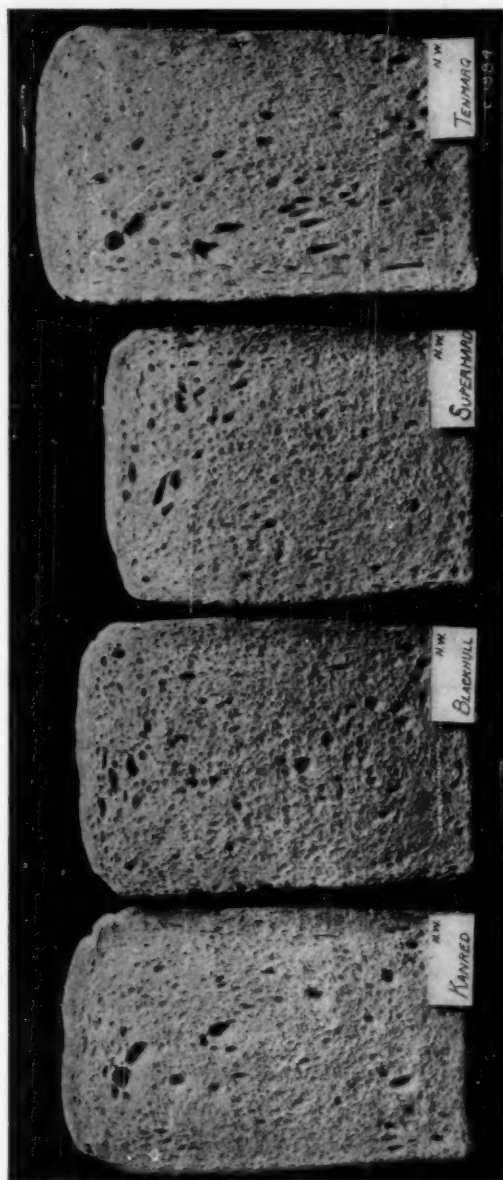


Fig. 1. Showing the results obtained by the mechanical modification test upon the baking quality of the varieties studied. Blackhull and Superhard are injured, while Kanred and Tenmarq are resistant to this treatment.

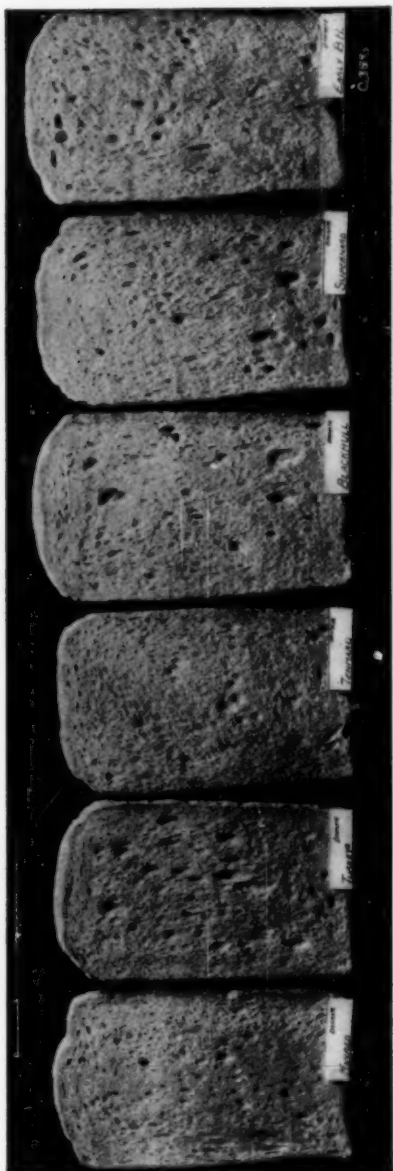


Fig. 2. Showing the reaction of the flours to the addition of 2 mgs. of potassium bromate. Blackhull, Superhard, and Early Blackhull are improved by the addition of small amounts of bromate, while Kanred, Turkey, and Tenmarq show no improvement or are injured by this treatment.



Fig. 3. Evaluation of Tenmarq, Kanred, and Blackhull by Chemist 13, reporting on 1929 crop wheats, Swanson (1930). Method was not reported, but it places the wheat in the same order of merit as the mechanical modification.

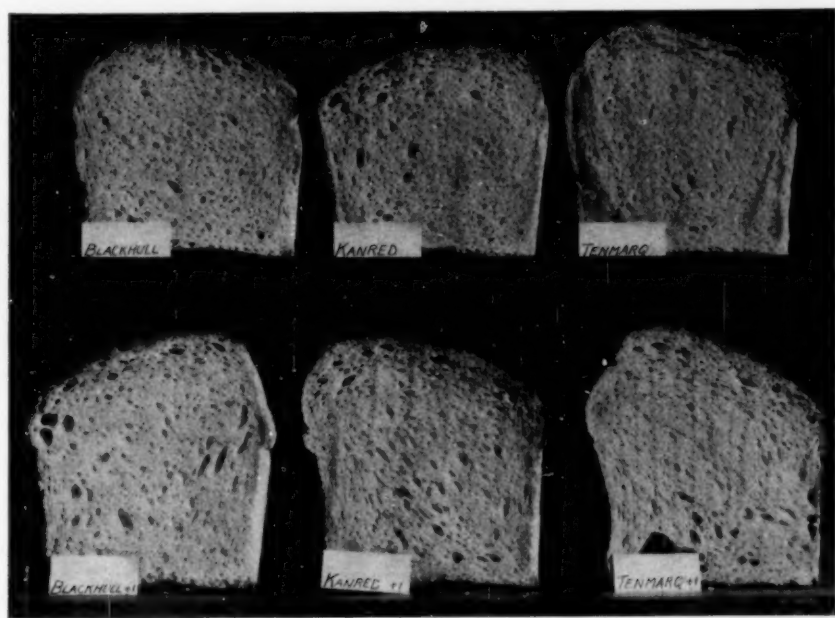


Fig. 4. Evaluation of Tenmarq, Kanred, and Blackhull by Chemist 11, reporting on 1929 crop of wheat, Swanson (1930). These loaves were made from the same flours as were those shown in Figure 3.

TABLE V
RESULTS OBTAINED BY THE THREE HOUR FERMENTATION METHOD

Variety	Unbleached		Bleached	
	Loaf volume	Loaf texture	Loaf volume	Loaf texture
	cc.	P.ct.	cc.	P.ct.
Blackhull	1980	95	1940	96
Superhard	1790	92	1870	90
Kanred	1890	95	1890	95
Tenmarq	1925	98	1950	97

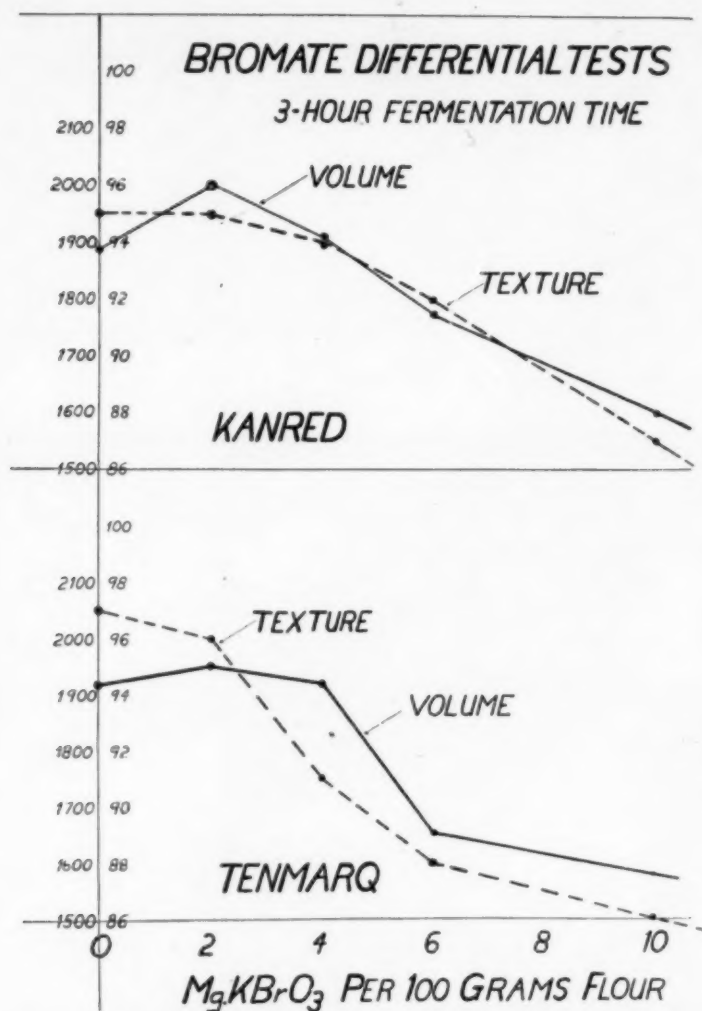


Fig. 5. Showing the reaction of flours milled from Kanred and Tenmarq wheat varieties to increasing amounts of potassium bromate. Kanred and Tenmarq are not improved by small amounts of bromate and are severely injured by increasing amounts.

Tests were also made on these flours by using the ordinary three hour fermentation-method, the method probably most used by cereal laboratories. The results on chlorine-bleached and unbleached flours are given in Table V.

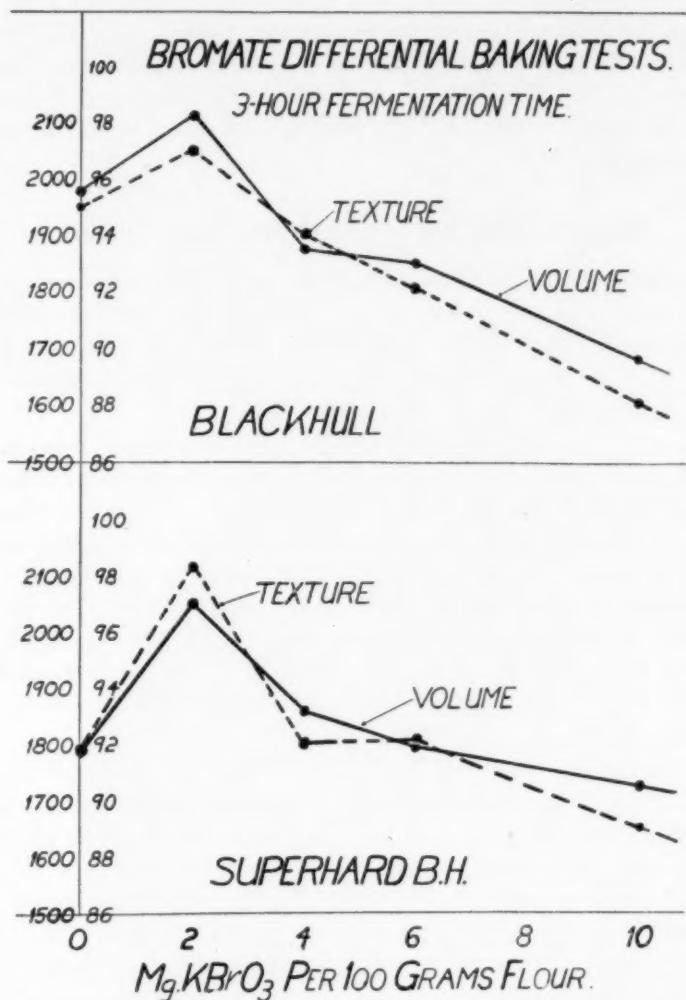


Fig. 6. Showing the reaction of flours milled from Blackhull and Superhard wheat varieties to increasing amounts of potassium bromate. Blackhull and Superhard are greatly improved by small quantities of bromate, but are severely injured by larger amounts.

The differences in results on Blackhull and Tenmarq are probably within experimental error and these two could be ranked first, with Kanred second, and Superhard last. Superhard appears to have benefited a little in loaf volume from bleaching. The results on the others reveal no marked effects from bleaching.

In Figure 5 are shown curves plotted from the data which were obtained by the differential bromate test while testing Kanred and Tenmarq flours. The results obtained with Blackhull and Superhard flours are to be found in Figure 6. In these tests bromate was used in increasing amounts, even to a very great excess. The slight response, if any, to 2 milligrams of bromate by Kanred and Tenmarq flours is in sharp contrast to the marked response given by Blackhull and Superhard flours. However, with large amounts of bromate, Blackhull and Superhard did not fare any better than did Kanred or Tenmarq, if as well.

Supplementary Tests Indicative of Flour Quality

WATTMETER TESTS: The high speed dough mixer used at the Kansas Agricultural Experiment Station is connected with a wattmeter which traces a curve showing variations in the use of power during mixing. These curves are shown in Figure 7. The reading is from left to right. The sharp rise in the curves shows that increasing amounts of power were required as the doughs developed, soon reaching a maximum and then decreasing. Both the rise and descent of the curves are much steeper for the flours milled from the variety Blackhull and its relatives, than for the flours milled from the variety Kanred and its relatives. This means that dough development takes place more rapidly in the Blackhull group than in the Kanred group, also that there is more danger of overmixing flours like Blackhull than those like Kanred. Tenmarq has the most gentle slope, both before and after maximum stiffness, or the point of highest resistance to mechanical action.

PHOSPHATIDE CONTENT: Working (1926) has shown that phosphatides have an important relation to the results obtained in baking. It was thought worth while to analyze the flours of these wheats for their phosphatide content. The method used in the determination was that of Rask and Phelps (1925). The following results were obtained: Blackhull, 1.07%; Superhard, 1.25%; Kanred, 1.03%; and Tenmarq, 1.05%. The figures do not show differences which could be definitely correlated with baking characteristics except for Superhard and even this may not be beyond experimental error.

UNIFORMITY OF PROTEIN CONTENT: The wheats which were used in the 1929 cooperative tests (Swanson 1930) as well as those in the studies just reported, varied in protein content. It was thought worth while to use samples of several wheat varieties which were so selected and blended as to have the same protein content. It was decided to get 10-bushel lots of Kanred, Blackhull, Tenmarq, and Marquis. The

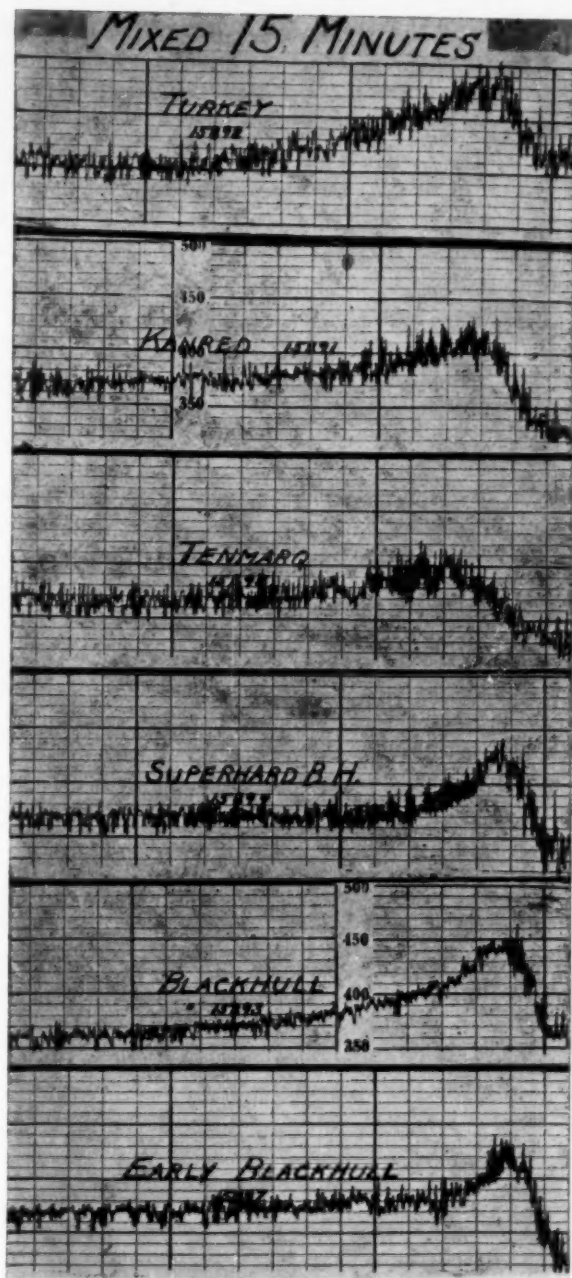


Fig. 7. Curves showing power input required in operating the high speed mixer used in the mechanical modification test.

writers had the cooperation of the Agronomy Department in locating and assembling these 10-bushel lots. A preliminary survey indicated that it was not possible to get Marquis wheat grown in Canada which would have a protein content in the usual range of the winter wheats. It was therefore decided to select lots of Kanred, Blackhull, and Tenmarq which could be blended in such manner that the protein would be near 12 per cent and then select another lot of Kanred which would have a protein content in the range of Marquis. Obviously, these wheats could differ in their characteristics as far as influenced by certain growth factors, although, the variation due to differences in protein were eliminated as far as possible. Enough of the different wheats were obtained so that it was possible to make up composite 10-bushel lots of each variety. These composite samples were graded by the Kansas City office of Federal Grain Supervision as follows:

TABLE VI
PHYSICAL CHARACTERISTICS OF WHEATS USED IN 1931 COOPERATIVE
BAKING TESTS

Variety	Class and sub-class	U. S. grade	Test weight	Dark, hard and vitreous kernels
			Pounds	P.ct.
Kanred L.P.	Dark Hard Winter	1	60.4	83
Blackhull	Hard Winter	1	60.8	78
Tenmarq	Hard Winter	2	59.5	60
Marquis	Hard Spring	1	61.8	97
Kanred H.P.	Dark Hard Winter	2	58.2	90

Tenmarq has the lowest percentage of dark, hard, and vitreous kernels, i.e. the highest percentage of "yellow berry." The Canadian sample of Marquis has a higher test weight and higher percentage of dark hard kernels than the sample of high protein Kanred. These five lots were milled to a 95 per cent straight flour on the college mill. Half of each lot of flour was bleached with Agene, leaving the other half unbleached. In packing, each 48 pound sack was numbered, and sack No. 1 from each variety was not used in the tests because of possible contamination with flour from milling the previous wheat.

The analysis of the wheats and flours are given in Table VII.

In addition to the usual moisture, ash, and protein tests, the doughs from these flours were tested for their gas producing and gas retaining capacities, and no significant differences were found. The hydrogen-ion concentration was also determined with the same results. The lecithin content also showed no marked variation. The swelling of gluten in N/50 lactic acid was also studied, making 20 individual determinations on the gluten from each flour. The three

TABLE VII

CHEMICAL ANALYSIS OF THE WHEATS AND FLOURS USED IN THE COOPERATIVE BAKING TESTS, 1931

Variety	Crude protein in wheat	Crude protein in flour	Ash in flour
	P.ct.	P.ct.	P.ct.
Kanred	12.00	10.85	0.43
Blackhull	12.35	11.30	.46
Tenmarq	12.30	10.85	.48
Kanred (high protein)	14.10	12.65	.51
Marquis (Canadian)	14.50	12.95	.44

lower protein wheats exhibited a somewhat lower swelling than the two higher protein wheats. That is, the gluten in the higher protein wheats seemed to have a greater hydration capacity than that of the lower protein wheats.

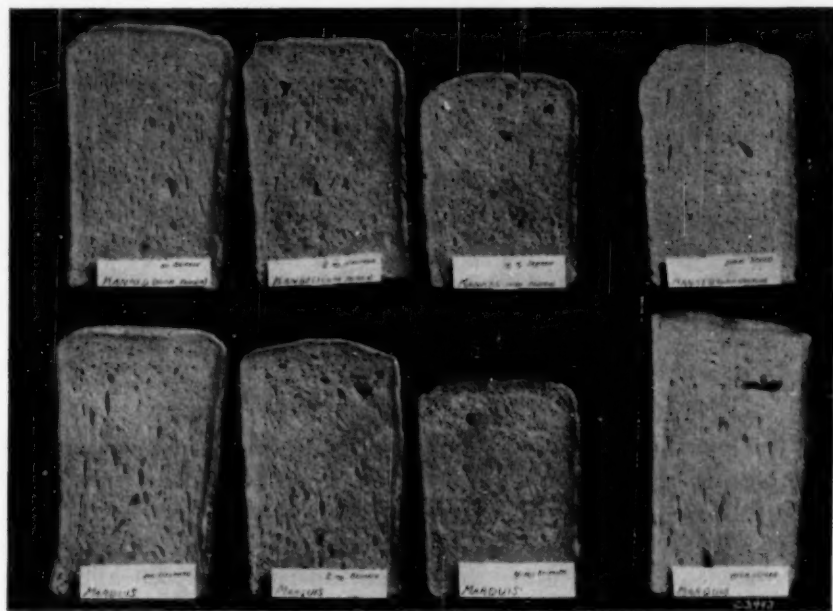


Fig. 8. Showing that Marquis has the same tendency to injury from bromate as Kanred. The "high speed" or mechanical modification test shows that Marquis has superior strength.

The five flours which are described in Table VII were baked using the several modifications in baking procedure listed in Table VIII. L.P. and H.P. distinguish the lower protein Kanred from the higher. The baking results are also given in Table VIII.

From these results the following conclusions may be drawn. The three hour fermentation method revealed no significant differences

among the five varieties; the method of mechanical modification places Marquis first, Tenmarq second, Kanred third, and Blackhull last. Blackhull shows the best resistance to bromate, Tenmarq and Marquis the least. Photographs of the loaves of bread made from Marquis and Kanred flours are shown in Figure 8. Marquis flour shows the same lack of resistance to bromate as Kanred flour.

TABLE VIII
RESULTS OF BAKING TESTS ON FIVE VARIETIES

Type of baking test	Variety	Loaf volume	Loaf texture
		cc.	P.ct.
Mechanical modification	Kanred L.P.	1870	95
	Blackhull	1820	90
	Tenmarq	1900	97
	Kanred H.P.	1760	94
	Marquis	2080	99
Three hour fermentation	Kanred L.P.	2030	97
	Blackhull	2020	97
	Tenmarq	2020	96
	Kanred H.P.	2020	96
	Marquis	2040	97
Bromate 2 mg.	Kanred L.P.	1900	92
	Blackhull	1960	92
	Tenmarq	1850	90
	Kanred H.P.	1880	90
	Marquis	1830	92
Bromate 4 mg.	Kanred L.P.	1670	88
	Blackhull	1690	88
	Tenmarq	1590	86
	Kanred H.P.	1570	86
	Marquis	1610	86

Resistance of the Various Flours to Bleaching

The resistance of flour to bleaching is of importance commercially. The baking qualities should not be injured by the amount of bleach needed to remove the yellow coloring matter. To test this, samples of the unbleached flour from each variety were bleached to various degrees with chlorine using the Agene experimental bleaching apparatus. The baking was done three days later. The results are given in Table IX.

Blackhull flour shows the most resistance to bleaching, while the flours milled from Marquis and Tenmarq show the least, with Kanred (both H.P. and L.P.) intermediate.

Cooperative Experiments

Samples of these five flours were sent to 16⁴ cereal chemists in federal, state, and commercial laboratories who had signified their

⁴ One chemist received flour from another series.

TABLE IX

RESULTS OF BAKING THE FLOURS FROM THE FIVE VARIETIES BLEACHED WITH VARYING DEGREES OF CHLORINE, THREE HOUR FERMENTATION METHOD

Variety	Amount of bleach	Loaf volume	Loaf texture	Loaf color
		cc.	P.ct.	P.ct.
Kanred L.P.	Unbleached	1950	99	93
	Half bleach	2050	98	96
	Full bleach	2105	97	98
	Double bleach	1935	98	99
Blackhull	Unbleached	2070	97	93
	Half bleach	2035	99	96
	Full bleach	2100	99	98
	Double bleach	2070	97	99
Tenmarq	Unbleached	2040	99	93
	Half bleach	1980	97	96
	Full bleach	1980	98	98
	Double bleach	1925	98	99
Kanred H.P.	Unbleached	2075	99	93
	Half bleach	2050	99	96
	Full bleach	2060	97	98
	Double bleach	2040	97	99
Marquis	Unbleached	2100	98	93
	Half bleach	2060	98	96
	Full bleach	2020	97	98
	Double bleach	1940	96	99

willingness to cooperate in the testing of these varieties. Very complete reports were received from these chemists together with comments on the results. Only the main conclusions, however, can be given in this paper. The different chemists are designated by numbers.

Chemist 1. The five flours were baked by three different methods. By each method Blackhull ranked first, Kanred second, and Tenmarq third. Comparing the Marquis with the high protein Kanred, Marquis was decidedly the better. The dough from Blackhull was poorer when mixed $3\frac{1}{2}$ minutes than when mixed for half that time, but it improved during fermentation and produced a good loaf of bread. Marquis and Kanred were closer together on long mixing than short mixing, but Marquis was still the superior. Longer mixing decreased fermentation tolerance. The figures show that Tenmarq had as good fermentation tolerance as Blackhull or Marquis.

Chemist 2. Tests were made on both the bleached and the unbleached flour samples using a differential fermentation time. "Taking the three samples with comparatively the same protein content, Blackhull gave us the better results both in the bleached and unbleached flours, Kanred was next, with Tenmarq not quite equal to either of the others. Of the higher protein wheats, Marquis was quite superior to the high protein Kanred."

Chemist 3. From the various data secured in the baking test, figures were computed for baking values as follows:

Variety	Basic bake		Commercial bake		Severe mixing— long fermentation		Bromated
	unbleached	bleached	unbleached	bleached	unbleached	bleached	unbleached
Marquis	89.5	92.3	103.3	96.1	79.8	89.8	92.5
Kanred H.P.	75.6	89.7	98.0	93.6	75.6	92.0	92.3
Kanred	77.3	86.7	91.5	93.8	81.8	85.0	82.6
Blackhull	78.4	92.9	102.2	97.3	79.6	91.6	85.6
Tenmarq	79.0	84.4	87.7	86.5	78.8	84.6	78.5

This chemist considers two points in the baking score as being within the experimental error. Marquis would place first; Blackhull, second; Tenmarq is equal to Kanred in three cases, and lower in four. A worker using the basic bake would arrive at the conclusion that Tenmarq was equal to Kanred, while if he used the bromated procedure he would be fairly sure that it was inferior.

Chemist 4. The fermentation ranges and absorptions were based on the viscosities of the flours and other analytical data. Three 100-gram loaves were baked from each flour. On the results of the baking tests, the flours were arranged in the following order of their desirability for baking in the company's plants: Tenmarq, Kanred H.P., Kanred L.P., Blackhull, and Marquis.

Chemist 5. A very extensive series of baking tests were made on both the bleached and the unbleached flours. The tests were repeated after a period of storage. The fermentation tests showed Tenmarq to be superior to Blackhull and low protein Kanred, but Tenmarq showed a marked breaking down in the stimulated loaf. The final order of merit was: Marquis, Blackhull, Tenmarq, Kanred H.P., and Kanred L.P.

Chemist 6. On the basis of the data submitted both on the bleached and unbleached flours we ranked them as follows: Tenmarq, Blackhull, Kanred L.P., Kanred H.P., and Marquis.

Chemist 7. Tests were made only on the unbleached samples and the flours were ranked as follows: Marquis, Kanred H.P., Kanred L.P., Blackhull, and Tenmarq.

Chemist 8. Tests were made on both the bleached and unbleached flours. The following statements were made: *Marquis*—Best results obtained with the 2½ and 3 hour fermentation periods. *Kanred H.P.*—This flour showed less fermentation tolerance than any of the others. *Kanred L.P.*—The bleached and unbleached samples were almost identical, showing no unusual characteristics but uniformly good. *Blackhull*—Undoubtedly the best flour of the three in the same protein

range. Absorption was considerably lower than in the others. *Tenmarq*—Probably the poorest flour of the group.

Chemist 9. The rating was made as follows, taking into consideration both the bleached and the unbleached flours: Marquis, Kanred H.P., Blackhull, *Tenmarq*, and Kanred L.P.

The following statement was made: "The *Tenmarq* was the lowest in volume but had a better texture than Kanred so would rate it in the fourth place. All the flours made a satisfactory bread, and I do not believe would be objectionable from the baker's standpoint. In the finished loaf *Tenmarq* had the brightest crumb color."

Chemist 10. The flours were tested in numerous ways. No matter how treated, *Tenmarq* would always rate the lowest. After several people had analyzed the reports the flours were rated in the following order: Marquis, Kanred H.P., Blackhull, Kanred L.P., and *Tenmarq*. Blackhull was improved decidedly in more than one respect by the addition of bleach. *Tenmarq* seemed to have an inherent weakness whether it was bleached or unbleached. Marquis had excellent fermentation tolerance and produced, under almost all conditions, a loaf of beautiful shred, good volume, and excellent interior characteristics.

Chemist 11. Marquis and *Tenmarq* were considerably superior in texture and grain of the loaf. Blackhull was the worst in the unbleached and unbromated samples. Blackhull was improved by bleaching and responded to the use of bromate but had the poorest color on account of the coarse texture and grain. Kanred, both samples, was not as good as Marquis and *Tenmarq* but was better than Blackhull when the latter was baked unbleached without the use of bromate. Marquis and *Tenmarq* had the least resistance to oxidizing reagents, and Blackhull the most. *Tenmarq* and Kanred were the lowest in loaf volume.

Chemist 12. All flours were baked in duplicate by the official basic procedure of the A. A. C. C. and also by certain modifications in use by the laboratory. The loaf volumes of the Marquis and the H.P. Kanred were nearly the same. Kanred was in all cases slightly more yellow than the Marquis. Grain and texture from the bleached samples were nearly identical. In the unbleached samples, Marquis was somewhat better than Kanred. On the whole the two samples were very similar. It was equally difficult to differentiate among the three varieties of the medium protein series. On the basis of loaf volume they would rank in this order: Blackhull, Kanred, and *Tenmarq*. On the basis of color, grain, and texture they would rank: *Tenmarq*, Kanred, and Blackhull. *Tenmarq* showed some damage due to bleaching while Blackhull was the most resistant followed

closely by Kanred. "On the basis of so few samples I do not feel that I can place one variety ahead of the others." None of the differences noted are beyond what would be obtained on one and the same variety.

Chemist 13. Tests were made both on the bleached and the unbleached samples. Kanred H.P. and Marquis are placed first, favoring Marquis a little; Blackhull is placed third; Tenmarq, fourth; and Kanred L.P. last. None of the five flours tested should give trouble in the bakeshop.

Chemist 14. The flours were baked three times with some variations on as many successive days. The tests indicated that Marquis was slightly superior to the high protein Kanred. In the second group of flours from the three wheat varieties it is not so easy to state our conclusions. On the basis of bread characteristics, Blackhull would rank first; while on the basis of dough characteristics, it would rank last. This sample produced an extremely flimsy dough. For household use it could be ranked ahead of Kanred and Tenmarq, but for use in shops using machines, it probably would be ranked last. As between Tenmarq and Kanred there was not much choice. Kanred had the smallest water absorbing capacity but had better color and would possibly produce better commercial flour.

Chemist 15. Two series of loaves were baked. In one series the flours were baked as received and in the other series each of the unbleached flours was blended with an 80% soft flour (7.7% protein) commercially milled from Canadian winter wheat which by itself makes a very inferior loaf of small volume. Experience has shown that small differences in the flours which are not observed when baked by the standard formula are often revealed by this method.

All five flours were considered to be strong and of very good baking quality, the Marquis and high protein Kanred wheats being slightly the best of this series. Bleaching caused a reduction in loaf volume with Tenmarq while no material changes occurred with the other varieties.

When baked alone the quality of the high protein Kanred flour was slightly the best while only slight differences could be observed in the remaining flours. The crumb color of all five flours was good and the differences noted among them were only slight. When baked in blends with 80 per cent low protein soft flour, Marquis and the high protein Kanred gave the best results, these were followed by Tenmarq, Blackhull, and the low protein Kanred.

Artificial bleaching increased the absorption of all flours by approximately 1% and at the same time improved the color of both the flour and the bread.

Chemist 16. This chemist made tests on another series of varieties, including Turkey, Blackhull, Superhard Blackhull, Early Blackhull, Tenmarq, and Fulhard. Superhard, Blackhull, and Early Blackhull produced the largest loaf volume and gave a good reaction against bromate, hence these two are placed first. Fulhard and Turkey gave good baking results. Tenmarq and Blackhull are somewhat poorer. Tenmarq reacts poorly towards bromate. This was possibly related to its low protein content.

Chemist 17. The bromate differential test was used on all samples and the doughs were mixed so as to eliminate variation from this source as much as possible. The following quoted statement seems to summarize the whole situation in regard to the tests made by these various chemists. "As I have previously stated, I consider it of very doubtful value to undertake to rank wheat varieties as to general superiority or inferiority on the basis of these tests. It is possible to rank them as to their comparative adaptability for some specific method of handling where the latter utility is known. If behavior toward oxidizing agents is indicative of general utility or baking strength then I would have to give the highest rating to Marquis and Blackhull, with Tenmarq bringing up the rear and Kanred intermediate. Just how big that 'if' is, I do not know. If water absorption is a measure of quality or strength, then Blackhull will lag behind the others. In this series Tenmarq showed the least potentiality for large loaf volumes."

It is somewhat difficult to present a concise summary of the findings of these chemists. Five of the chemists judged the flours in these respective groups: Marquis with the high protein Kanred; and the three medium protein, Blackhull, Kanred (low protein), and Tenmarq. Four of these placed Marquis ahead of Kanred, and one found no essential differences in these two. Among the three medium protein wheats, two chemists found no essential differences. The other three placed Blackhull first, Kanred second, and Tenmarq last.

The other eleven chemists ranked the five flours, or we attempted to rank them on the basis of the submitted data or statements. One of these chemists ranked the flours as all strong; several said that the flours could be ranked in different ways depending on the objective. The following is an attempted summary.

Judging by these results it may be said that Tenmarq, as a new variety is fully equal to any of the older and more extensively tested hard red winter wheats. In these tests Marquis appears superior, but this may be accounted for in part by the higher protein, and the greater per cent of hard flinty kernels as compared with Tenmarq.

Variety	Rank				
	1	2	3	4	5
Marquis	8	1			2
Kanred H.P.		8	2	1	
Kanred L.P.		3	4	2	2
Blackhull	1	4	4	2	
Tenmarq	3	1	2	3	2

Conclusions

New wheat varieties are developed to meet the needs of wheat producers. In addition to having superior agronomic characteristics they must also be as good as, or better than the older varieties from the milling and baking standpoint.

Methods of making small scale milling tests that are entirely satisfactory have not been developed.

The protein content is so much influenced by soil and season that it cannot be used alone in evaluating new wheat varieties.

Methods of conducting the baking test vary so much that unanimity of opinion is not obtained when several wheat varieties are tested by a group of cereal chemists. Workers in flour mill and bakery laboratories seem to have perfected their methods to a high degree for the control of the manufacturing operations of the mill and for evaluating the flour for a known class of trade.

For evaluating new wheat varieties it is best to study baking performance in comparison with old and tested varieties, and also to measure certain characteristics. Two of these seem to be hereditary, namely; resistance to mechanical action and response to oxidizing agents, usually potassium bromate. These characteristics seem to be antagonistic and the varieties which have one seem to lack the other. Thus Tenmarq has a high degree of resistance to mechanical action, but is easily injured by oxidizing agents, while Blackhull has a low resistance to mechanical action, but is greatly benefited by oxidizing agents. Such a condition appears to be one reason why such conflicting results are obtained by different workers on the same varieties when different testing procedures are used.

Future progress demands that more attention be given to measuring certain characteristics, not only the two mentioned but several others, rather than depending on a general procedure such as the baking test as now used.

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BULLETIN REVIEW

Factors for Coverting Percentages of Nitrogen in Foods and Feeds into Percentages of Proteins. (Circular 183C.) D. Breese Jones, principal chemist, protein and nutrition division, chemical and technological research. Bureau of Chemistry and Soils. 22 pp. August, 1931.

This circular, which is of interest mainly to food specialists, explains the magnitude of errors arising from the use of wrong conversion factors in estimating protein content of foods, and illustrates these errors by citing the figures for a number of foods. It states that the use of the conversion factor 6.25, by which percentages of nitrogen are multiplied to estimate protein in foods and feeds, frequently is inaccurate because this method rests on two assumptions neither of which is necessarily correct—namely, that all the nitrogen in food material is protein nitrogen, and that all proteins contain 16 per cent nitrogen. The circular gives the nitrogen content of more than 121 different proteins isolated from plant and animal sources in which nitrogen content ranges from 13 per cent to more than 19 per cent.

Copies of the above publication may be obtained by writing to the Division of Publications, Office of Information, United States Department of Agriculture, Washington, D. C.

THE SIGNIFICANCE OF HYDROGEN-ION CONCENTRATION IN PANARY FERMENTATION

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The ball quinhydrone method of measuring the H-ion concentration of flour-water mixtures of dough consistency developed by us (1931) has been used for tracing the changes in pH of fermenting doughs. As a preliminary it was necessary to ascertain to what extent the incorporation of quinhydrone into a yeast dough affected the fermentation. Gas tests on a dough with which quinhydrone had been mixed at making showed that apparently this addition stopped fermentation as no gas evolution took place. This was confirmed by pH measurements which showed no change in H-ion concentration to take place after the addition of the quinhydrone. Thus with a dough containing 2% yeast and 1.0% of quinhydrone the pH after 15 minutes, was 5.65; 30 minutes, 5.64; 45 minutes, 5.64; 60 minutes, 5.65; 120 minutes, 5.65. This complete prevention of fermentative action of yeast by quinhydrone is of obvious convenience, as it is possible by this means to stop fermentation in the dough at any desired moment.

TABLE I
CHANGES IN pH OF REPLICATE SAMPLES OF DOUGH DURING FERMENTATION

Time of fermentation	pH of dough after 15 and 30 minutes							
	Sample I		Sample II		Sample III		Averages	
	at		at		at		at	
	15 mins.	30 mins.	15 mins.	30 mins.	15 mins.	30 mins.	15 mins.	30 mins.
5 mins.	5.71	5.68	5.74	5.72	5.71	5.68	5.72	5.69
60 mins.	5.54	5.55	5.50	5.52	5.54	5.54	5.53	5.54
125 mins.	5.51	5.51	5.47	5.45	5.41	5.41	5.46	5.46
185 mins.	5.48	5.50	5.45	5.44	5.47	5.46	5.47	5.47
245 mins.	5.43	5.43	5.40	5.39	5.37	5.37	5.40	5.40
305 mins.	—	5.39	—	5.41	—	5.39	—	5.40
360 mins.	5.43	5.39	5.38	5.38	5.34	5.33	5.38	5.37

In Table I are given the results of the measurement of the change in pH of a dough during fermentation. The dough was made from 28 ozs. flour with 2% yeast and 1.25% salt at 80° F. At hourly

intervals the dough was rolled flat and three 15-gram samples taken. With each of these samples 0.1 gm. quinhydrone was at once thoroughly incorporated and the pH measured after 15 and 30 minutes.

The figures show that the difference between the 15 and 30 minute pH readings varied from 0.00 to 0.04, but that the difference between the pH of different samples taken at the same time is much greater, viz., 0.02 to 0.10. This is probably due to the dough not being homogeneous, an idea borne out by the fact that better agreement is obtained between samples by making each consist of three or four smaller samples taken from different parts of the dough. Most of our pH figures for doughs have been obtained on such composite small samples.

Comparison of Changes in pH and in Gas Production During Fermentation

In Figure 1 are drawn curves showing the relation of the pH and of gas production of a dough made with 2% yeast at 80° F. to the time of fermentation. The two curves have very different shapes, the

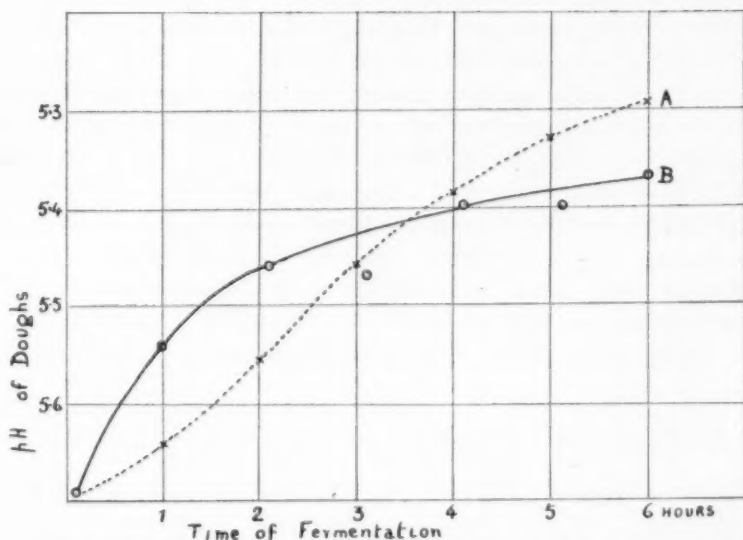


Fig. 1. Showing comparison between rate of gas production and change in pH of a dough during fermentation.

- A. Gas production curve.
- B. pH curve.

differences being shown up in the hourly changes in pH and gas production given in Table II. These figures show that the change in H-ion concentration in the dough is greatest in the first hour, being halved in the second, and halved again in the third hour. On the other hand, the hourly gas production of this dough rises to a maximum

TABLE II
HOURLY CHANGES IN GAS PRODUCTION AND IN pH OF A FERMENTING DOUGH

Time hours	Hourly change in	
	pH	Gas production (cc.)
1st	0.15	57
2nd	.08	86
3rd	.04	99
4th	.02	70
5th	.02	58
6th	.01	36

in the third hour (when it is nearly double that of the first hour), and then falls off more or less rapidly. One concludes from this that either the production of acid in the dough during fermentation does not follow the same course as the production of carbon dioxide, or that the buffering must greatly increase with time of fermentation thus slowing up the change in H-ion concentration even though the actual amount of acid produced were increasing. The buffer value of a dough measured (as described by Halton and Fisher (1928)) after 1 and after 3 hours' fermentation was 0.60 and 0.59 respectively, thus showing very little change. This slight change is substantiated by the very slight changes previously recorded by us (1929) in the buffer values of extracts of loaf crumbs measured over wide ranges of fermentation time. It appears therefore that in the first hour's fermentation when gas production is extremely slow, the yeast is showing its greatest activity as an acid producer. The greater part of the acidity produced during panary fermentation is produced in the very early stages, very little change in pH occurring in the later stages of fermentation.

Similar phenomena are observed with different flours and with different brands of yeast. In Tables III and IV, and Figure 2, are given some results obtained with two commercial straight-run flours

TABLE III
HOURLY GAS PRODUCTION OF FOUR DOUGHS¹ MADE FROM TWO DIFFERENT FLOURS
AND TWO DIFFERENT BRANDS OF YEAST

Time of fermentation	Flour S. 186		Flour S. 195	
	D.C.L. yeast	N.G. & S.F. yeast	D.C.L. yeast	N.G. & S.F. yeast
	cc.	cc.	cc.	cc.
1st hour	50	52	44	59
2nd hour	78	102	84	88
3rd hour	102	127	103	120
4th hour	118	100	124	112
5th hour	72	49	79	76
6th hour	42	30	56	44
Total gas in 6 hours	462	460	490	499

¹ 50 gms. flour, 1.0 gm. yeast, 0.625 gm. salt, 25 ccs. water, 80° F.

(labelled S. 186 and S. 195) and two different brands of yeast—D.C.L. (of English manufacture), and N.G. and S.F. yeast (manufactured in Holland). In each case the dough was made from 50 grams flour with

TABLE IV
HOURLY PH'S OF FLOUR DOUGHS¹ MADE FROM TWO DIFFERENT FLOURS AND TWO DIFFERENT BRANDS OF YEAST

Time of fermentation	Flour S. 186		Flour S. 195	
	D.C.L. yeast	N.G. & S.F. yeast	D.C.L. yeast	N.G. & S.F. yeast
10 mins.	5.82	5.78	5.73	5.71
98 mins.	5.64	5.45	5.58	5.50
132 mins.	5.62	5.44	5.61	5.42
190 mins.	5.52	5.50	5.54	5.40
280 mins.	5.52	5.44	5.48	5.35
367 mins.	5.49	5.43	5.51	5.33

¹ 50 gms. flour, 1.0 gm. yeast, 0.625 gm. salt, 25 ccs. water, 80° F.

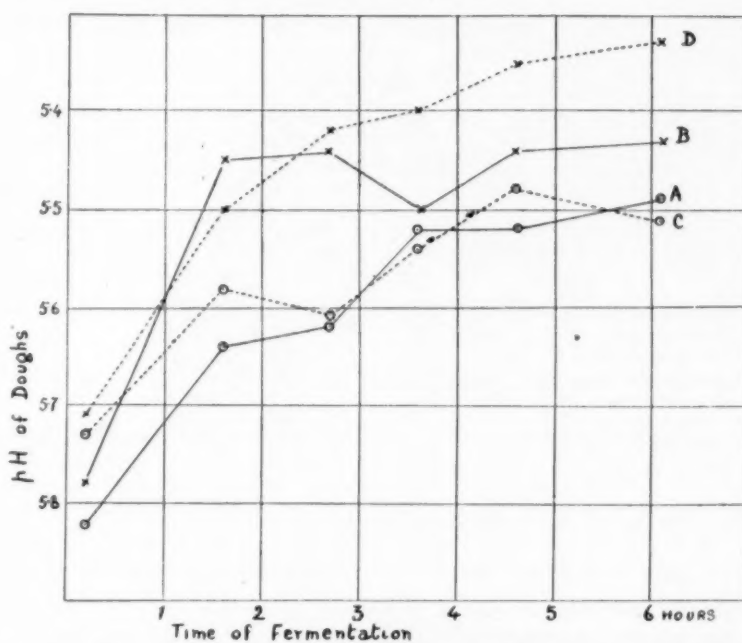


Fig. 2. Showing change in pH during fermentation of doughs made from two commercial straight-run flours (labelled S. 186 and S. 195) and two different brands of yeast (D.C.L. and N.G. & S.F.).

- A. S. 186 with D.C.L. yeast.
- B. S. 186 with N.G. & S.F. yeast.
- C. S. 195 with D.C.L. yeast.
- D. S. 195 with N. G. & S.F. yeast.

2% yeast, 1.25% salt, 50% water, and maintained at a temperature of 80° F. The figures given in Table III indicate that with both flours the N.G. and S.F. yeast gave the greater production of gas during the

first three hours after which its gas producing activity fell off relatively more rapidly so that at the end of six hours both yeasts had produced substantially the same quantities of gas. On the other hand, Table IV shows that with all four doughs the greatest change in H-ion concentration was during the first hour or so, and that as time of fermentation increased the hourly change in pH decreased. The dough made from flour S. 186 and N.G. and S.F. yeast appeared anomalous in that the whole change in pH occurred in the first one and a half hours after which no further change occurred. It is worthy of note that although total gas production was the same for both yeasts at the end of six hours' fermentation the doughs made with N.G. and S.F. yeast remained of higher H-ion concentration throughout.

Effect of the Addition of Malt Extract and Ammonium Phosphate, and of Cane Sugar on pH and Gas Production During Fermentation

In Table V are given gas production figures for flour S. 189 with 2% N.G. and S.F. yeast, and with and without the addition of 0.1%

TABLE V
EFFECT OF ADDITION OF MALT EXTRACT AND AMMONIUM PHOSPHATE AND OF CANE SUGAR ON THE HOURLY GAS PRODUCTION AND pH'S OF A DOUGH

Time	No additions		Plus M.E. & A.P. ¹		Plus cane sugar	
	Hourly gas production	pH ²	Hourly gas production	pH ²	Hourly gas production	pH ²
No fermentation	—	5.73	—	5.73	—	5.73
1st hr. fermentation	76	5.54	80	5.50	82	5.52
2nd hr. fermentation	104	5.48	114	5.41	104	5.44
3rd hr. fermentation	100	5.43	126	5.34	105	5.38
4th hr. fermentation	70	5.40	115	5.30	108	5.34
5th hr. fermentation	46	5.39	66	5.26	111	5.30
6th hr. fermentation	29	5.37	35	5.23	91	5.28
Total gas in 24 hrs.	619		779		865	

¹ 0.1% malt extract (Lintner value 250°) and 0.05% acid ammonium phosphate.

² The pH figures are taken by interpolation from the curves of Fig. 3.

highly diastatic malt extract (Lintner value 250°) and 0.05% ammonium phosphate, and of 2% cane sugar. The addition of malt extract and ammonium phosphate prolonged the period of high gas production for an hour; the sugar prolonged it for three hours. The effect of such additions on the change of H-ion concentration during fermentation in a dough made from the same flour sample (S. 189) but using a fresh sample of N.G. and S.F. yeast is also shown in Table V and in Figure 3. Although the addition of sugar caused a greater prolongation of the period of high gas production than did malt extract and ammonium phosphate, it had less effect on the changes in H-ion concentration

during fermentation of the dough. Presumably the activity of the enzymes present in the malt extract is a factor in the increased rate of change of pH, but the total effect (about 0.1 pH in a three or four hours' fermentation) is probably too small to be of any direct importance.

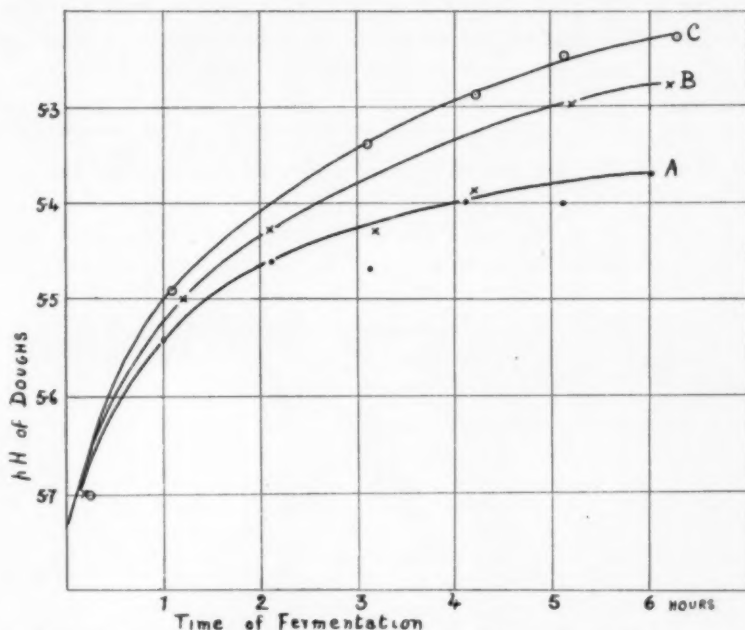


Fig. 3. Showing effect of additions of sugar, and of malt extract and ammonium phosphate on the change in pH during fermentation in a dough.

- A. No addition.
- B. With sugar.
- C. With malt extract and ammonium phosphate.

Effect of "Knocking Back" on Gas Production and on Change of pH in Doughs

To measure the effect of knocking back on gas production four doughs were made from flour S. 189 with 2% N.G. and S.F. yeast, 1.25% salt, 50% water at 80° F. One of these was at once put into the gas measuring apparatus and its gas evolution noted at intervals. The remaining three doughs were kept in an incubator at the same temperature as that at which the gas production of the first dough was being measured (80° F.). At the end of one hour these three doughs were knocked back and one of them put into the apparatus for measurement of gas production. The remaining two were left a second hour in the incubator before being again knocked back. One of these was then put into the gas measuring apparatus and the third dough was given a final knock back after three hours, after which its

rate of gas production was measured. The gas production for the second dough was not measured during the first hour but as during this time it was kept at the same temperature as the first dough one can assume that the actual gas evolution during this period was the

TABLE VI
EFFECT OF "KNOCKING BACK" A DOUGH ON HOURLY GAS PRODUCTION

Time of fermentation	No. of hourly "knocks back"			
	0	1	2	3
Hourly gas production (ccs.)				
1st hour	50	50	50	50
2nd hour	86	86	86	86
3rd hour	103	103	103	103
4th hour	90	94	100	106
5th hour	46	57	76	94
6th hour	29	36	37	43

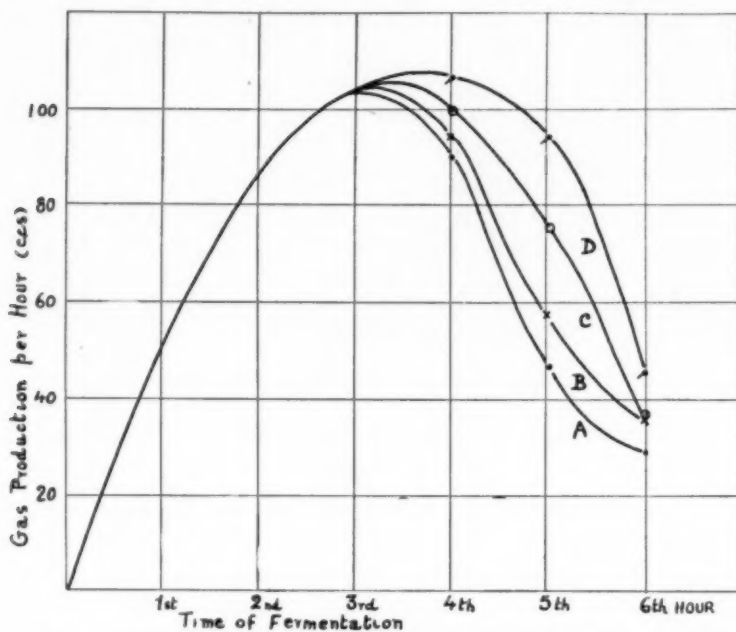


Fig. 4. Showing effect of knocking back on the hourly gas production of a dough.

- A. No knocks back.
- B. One knock back.
- C. Two knocks back.
- D. Three knocks back.

same for both doughs. Similarly, it can be assumed that the actual gas production of the third dough during the first two hours was the same as that of the second dough, and that of the fourth dough during the first three hours was the same as that of the third dough. Table

VI and Figure 4 are based on the above assumptions and on the gas evolutions actually measured; the actually measured gas productions are given in italic type in Table VI. Table VI and Figure 4 show that "knocking back" has no immediate effect on gas production. Thus the gas evolution for all four doughs was the same up to and including the third hour. During the fourth hour the doughs with 0, 1, 2 and 3 knocks back gave off 90, 94, 100 and 106 cc. of gas, and during the fifth hour 46, 57, 76 and 94 cc. respectively. This prolongation of the period of high gas production was proportional to the number of knocks back, three knocks back being enough to prolong the period for an extra hour. During the fifth hour the dough which was not knocked back did not produce sufficient gas to give a satisfactory loaf, whereas the dough which had been given three knocks back gave off ample gas and more than twice as much as the former.



Fig. 5. Showing slices cut from the middle of loaves made from doughs that had not been knocked back in front of half loaves made from doughs that had been knocked back. From left to right the loaves had $3\frac{1}{4}$, 4 and $4\frac{3}{4}$ hours' fermentation.

To show the practical significance of these results, three pairs of doughs were made which were baked after $3\frac{1}{4}$, 4, and $4\frac{3}{4}$ hours' fermentation respectively. One of each pair was left untouched from the time of making until it was scaled off into the tin. The other of the pair was knocked back each hour. The resultant loaves are shown in Figure 5. An idea of their relative volumes is given by the sums of the two—longitudinal and transverse—perimeters which were as follows:

	Knocked back	Not knocked back
$3\frac{1}{4}$ hours' fermentation	50.8"	48.7"
4 hours' fermentation	49.3"	44.7"
$4\frac{3}{4}$ hours' fermentation	46.0"	42.1"

Both $3\frac{1}{4}$ -hr. loaves were good, that made from the dough which had been knocked back being slightly the better. Of the two 4-hr. loaves

that which had been knocked back was equal to the $3\frac{1}{4}$ -hr. loaves, whereas the other with its much smaller volume and tough crumb had obviously lacked gas. Both $4\frac{3}{4}$ -hr. loaves showed lack of gas, but here again that which had been knocked back was much the better and larger. This prolongation of the period of good gassing by knocking back is of obvious practical importance to the baker. If, owing to accident or other untoward circumstances, a baker is compelled to let his dough lie an hour or so longer than is desired, his common practice is to avoid knocking back in order to slow up fermentation; the dough is allowed to lie undisturbed to prevent over-ripeness. Defective gassing frequently results in consequence and unsatisfactory bread is obtained. With additional knocking back better gassing is obtained and consequently better bread. In this respect, then, the practical baker's "practice" seems to be wrong; more, rather than fewer, knocks back appear to be the best means of dealing with such delayed doughs.

To see what effect knocking back has on the change of H-ion concentration, a dough was made up from 84 ozs. of a straight run flour (S. 202), 2% N.G. and S.F. yeast, and the necessary salt and water, and was immediately scaled off into one 42 oz. dough and seven 12 oz. doughs. Samples were immediately taken from one of the latter and their pH measured, the remaining doughs being left to prove at 80° F. At approximately hourly intervals the 42 oz. dough was knocked back by rolling out and samples taken for pH determination. One of the small doughs was also rolled out, but after samples were taken from it, it was discarded so that at each hour a fresh untouched dough was used.

TABLE VII
EFFECT OF "KNOCKING BACK" ON THE pH OF DOUGHS

The large dough was knocked back at hourly intervals; the small doughs were knocked back once only, i.e. immediately before the pH was determined.

Time of fermentation	Small doughs			Large dough		
	Duplicate samples		Mean pH	Duplicate samples		Mean pH
10 mins.	5.64	5.64	5.64	—	—	—
63 mins.	5.47	5.44	5.45	5.44	5.45	5.44
125 mins.	5.44	5.44	5.44	5.44	5.43	5.43
190 mins.	5.43	5.43	5.43	5.44	5.45	5.44
245 mins.	5.42	5.43	5.42	5.41	5.40	5.40
300 mins.	5.39	5.41	5.40	5.43	5.48	5.45
365 mins.	5.43	5.46	5.44	5.41	5.42	5.41

Table VII and Figure 6 show the result of these tests, no significant difference being shown between the pH's of the larger dough which was knocked back each hour and the smaller doughs which were

knocked back once only. Moreover, no significant change in pH occurred in any of the doughs after the first hour.

Evidently knocking back has no effect on the acid producing activities of the yeast, but only on the gas producing power. Further, the effect of knocking back does not appear to be a stimulation of the yeast as is sometimes stated (e.g., owing to the introduction of oxygen)

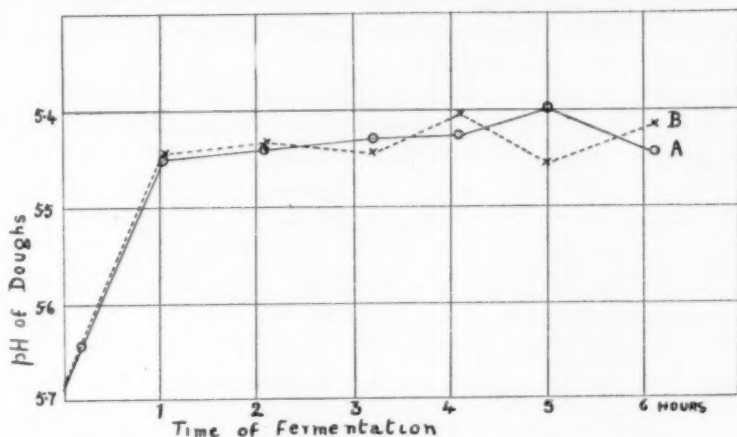


Fig. 6. Showing effect of knocking back on the change in pH during fermentation of a dough.

- A. No knocks back.
- B. Knocked back each hour.

since the gas production curve (Figure 4) immediately before and after knocking back is smooth and shows no change of direction; the gas production curve continues on its way without change of direction for some time after the dough has been knocked back; the more numerous the knocks back the longer is the period of steady gas production. The results suggest that the apparent stimulation is due to the yeast being brought into contact with a fresh food supply as a result of the mechanical treatment of the dough during knocking back.

Summary

The hydrogen-ion concentration of dough changes comparatively little during fermentation. During four hours with 2% yeast at 80° F. the change in pH of doughs of straight run flours is of the order of 0.2 to 0.4 only.

Whereas rate of gas production rises to a maximum after which it falls off rapidly, change in pH is greatest in the earliest stages of fermentation, the changes slowing up rapidly as fermentation proceeds. The greater part of the change in pH occurs in the first hour when gas production is comparatively slow. There is no relation, however, between rate of gas production and rate of change of pH.

Addition of highly diastatic malt extract and ammonium phosphate or of cane sugar has marked effect in prolonging the period of high gas production, but has relatively little effect on the pH of dough.

"Knocking-back" has no appreciable effect on dough pH but has marked effect in prolonging the period of high gas production. Additional knocks back should be given to doughs which are delayed in their passage to the oven in order to prolong their period of good "working." Bakers generally leave such doughs undisturbed; this appears to be unsound practice.

The evidence obtained so far suggests strongly that change in pH can play only a very minor part in panary fermentation and in dough ripening.

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FACTORS THAT INFLUENCE THE RATE OF ABSORPTION OF WATER BY WHEAT

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The tempering of wheat has long been a favorite subject for discussion with both cereal chemists and millers. Swanson and Pence (1930) presented much experimental data from which they drew the following conclusions: (1) At 64° F., or above, water penetrates the wheat kernel in two hours and is evenly divided throughout the endosperm. (2) The wheat kernel is not inclosed in a non-permeable membrane but absorbs water through the entire bran surface exposed to tempering action. (3) The bran coat has greater affinity for water than the endosperm. (4) Temperature influences the rate at which water may enter the wheat.

The paper by Miller (1931) presents another interesting phase of wheat tempering, in which the whole process of water absorption, or permeation, is explained on the basis of capillary action.

Pap (1931) examined 286 wheat samples and found wide differences in their hygroscopicity. Samples were held in a humid atmosphere for varying lengths of time. He concludes that climatic and soil conditions are the vital factors, the influence of variety being of subordinate importance.

Experimental

The first part of this work has to do with the amount of water absorbed by wheat when immersed. The second part deals with the rate of penetration of water into the wheat kernel when tempered in the ordinary way.

Method of Study. In general the procedure of Swanson and Pence (1930) was followed: Ten-gram portions of the clean grain were immersed in water and then centrifuged for 30 seconds, in a basket 2 inches in diameter, made of 2 layers of 16 mesh wire, at the rate of 3200 R.P.M. The samples were removed and weighed immediately. The results are reported as gain in weight, in grams, of the 10-gram sample. All determinations were made in triplicate, which never varied more than 0.03 gram.

For the second part of the experiment 500-gram lots of wheat were tempered by the addition of 25 grams of water and allowed to stand

for varying lengths of time in closed containers having a capacity for 1000 grams of wheat. One hundred-gram portions, including one from the dry wheat, were milled by grinding once through a Hobart laboratory mill and immediately bolted in such a manner as to separate the wheats into three parts consisting essentially of bran, middlings, and flour, in fairly equal portions. Moisture determinations were made on the different separations.

Influence of Variety, Time of Immersion and Temperature of Water on the Rate and Amount of Absorption

Table I shows the effect of variety, time of immersion, and temperature of water, on the rate and amount of absorption. Although variety is of great importance it is not the determining factor. Turkey shows consistently greater absorption than Marquis, while the very soft Red Russian absorbs less water than almost any other variety. Absorption varies with length of time immersed and temperature of immersion water.

TABLE I

THE EFFECT OF VARIETY, LENGTH OF TIME IMMERSSED AND TEMPERATURE OF IMMERSION WATER ON THE RATE AND AMOUNT OF ABSORPTION

Variety	Temperature of water	Weight gained when immersed for—					Crude protein	Moisture
		½ min.	1 min.	5 min.	30 min.	60 min.		
	°F.	Grams	Grams	Grams	Grams	Grams	P.ct.	P.ct.
Marquis	56	0.35	0.44	0.67	0.97	1.25		
Marquis	103	.48	.56	.76	1.42	1.80	14.5	10.1
Turkey	59	.45	.47	.65	1.10	1.49		
Turkey	100	.55	.57	.87	1.45	1.95	13.0	10.3
Baart	54	.39	.49	.67	.95	1.42		
Baart	100	.47	.58	.87	1.28	1.65	13.8	9.9
Hard Federation	56	.35	.42	.63	.96	1.23		
Hard Federation	100	.42	.51	.82	1.36	1.89	10.9	11.3
Club	61	.36	.45	.61	.90	1.21		
Club	102	.43	.53	.76	1.26	1.83	9.5	10.7
Red Russian	57	.28	.38	.63	1.00	1.33		
Red Russian	100	.49	.52	.75	1.39	1.62	8.5	11.7

Influence of Protein Content of Sample on Amount of Water Absorbed

The data shown in Tables II and III were derived from experiments where the wheat samples were held at a temperature of 76° F. and then immersed in water at 56° F. for 1 minute. The time interval of 1 minute was considered as comparable to the period of contact that wheat has with an excess of water in the process of wheat washing.

The variations in weight shown in Table II are very slight and are probably due to the greater percentage of small kernels in the higher protein wheats rather than to any difference in protein.

TABLE II

VARIATIONS IN THE AMOUNT OF WATER ABSORBED BY SAMPLES OF WHEAT OF DIFFERENT PROTEIN CONTENT

Variety	Crude protein	Gain in weight
	P.ct.	Grams
Marquis	13.5	0.43
Marquis	14.5	.44
Turkey	7.6	.40
Turkey	8.1	.42
Turkey	8.6	.43
Turkey	11.1	.46
Turkey	13.3	.47
Kota	10.4	.30
Kota	11.9	.30

Influence of Scouring on the Amount of Absorption

The effect of scouring on the amount of water absorbed was next studied. The scouring was accomplished by passing the samples twice through a laboratory scouring machine set especially close. The scouring action was sufficiently severe to materially change the physical appearance of the grain and raise the test weight per bushel approximately 2 pounds. The data given in Table III show quite conclusively that scouring affected the amount of absorption in all cases. The increase in absorption was much greater with some varieties than with others.

TABLE III

THE EFFECT OF SCOURING ON THE AMOUNT OF ABSORPTION

Variety	Treatment	Gain in weight
		Grams
Marquis	Not scoured	0.48
Marquis	Scoured	.77
Turkey	Not scoured	.47
Turkey	Scoured	.56
Fortyfold	Not scoured	.41
Fortyfold	Scoured	.72

Effect of Size of Kernel on the Rate and Amount of Absorption

A sample of Marquis wheat was divided into two portions by the use of 8 and 10 mesh screens. The large kernels were retained on the 8 mesh screen while the smaller kernels passed through the 8 and over the 10 mesh screen. Both lots of wheat were equally hard and vitreous. The data from these experiments are shown in Table IV. The data indicate that the smaller sized kernels absorb moisture the most rapidly.

TABLE IV

THE EFFECT OF SIZE OF KERNEL ON THE RATE AND AMOUNT OF ABSORPTION

Kernel size	Kernels in 10 grams	Weight gained when immersed for—					Crude protein	Moisture
		½ min.	1 min.	5 min.	30 min.	60 min.		
		Grams	Grams	Grams	Grams	Grams	P.ct.	P.ct.
Large	365	0.43	0.49	0.77	1.19	1.51	13.68	10.3
Small	500	.51	.56	.84	1.37	1.71	13.92	10.2

Influence of Time, Temperature, and Variety on Rate of Absorption of Water by Wheat

Proper tempering is not a question of absorption but of penetration of moisture into the wheat kernel. Several factors influence this rate of penetration. A certain amount of practical knowledge regarding these variables is essential to intelligent milling in districts such as the Pacific Northwest, where a dozen different wheat blends may be brought onto the mill in a single week.

Water penetrates to all parts of the wheat kernel in 2 or 3 hours. The differences in percentage of moisture shown, between the short temper of 1, 2, and 3 hours, and the 23 hour period, is due to the greater loss of moisture in grinding and bolting the former. This would indicate that moisture is held in some very different way when the grain is allowed to stand for several hours.

The two lots of Hard Federation were the same but were subjected to different temperatures.

TABLE V

THE EFFECT OF VARIETY, TIME, AND TEMPERATURE ON THE RATE OF ABSORPTION

Variety	Product	Moisture in products from dry wheat	Moisture in wheat when tempered for—				Crude protein	Test weight	Temperature of		
			1 hr.	2 hr.	3 hr.	23 hr.			Room	Wheat	Water
		P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	Pounds	°F.	°F.	°F.
Baart	Wheat	9.8	13.6	13.4	13.8	13.8	10.3	59.1	75	74	60
Baart	Bran	9.4	13.3	13.3	13.5	13.9					
Baart	Middlings	9.8	13.1	13.1	12.8	13.7					
Baart	Flour	10.1	13.2	12.9	12.9	13.6					
Turkey	Wheat	9.1	13.2	13.4	13.8	13.7	15.8	59.6	74	73	60
Turkey	Bran	8.5	13.4	13.4	13.9	13.4					
Turkey	Middlings	9.1	12.7	12.7	12.8	13.1					
Turkey	Flour	9.3	12.7	12.9	12.8	13.2					
Hard Federation	Wheat	10.8	13.7	14.3	14.6	15.4	11.9	58.6	74	85	60
Hard Federation	Bran	10.4	13.6	14.1	14.5	15.8					
Hard Federation	Middlings	10.5	13.1	13.3	13.7	14.9					
Hard Federation	Flour	10.7	13.1	13.2	13.5	14.7					
Hard Federation	Wheat	10.7	13.4	13.6	13.9	14.8	11.9	58.6	44	45	49
Hard Federation	Bran	10.3	13.7	13.8	13.9	14.9					
Hard Federation	Middlings	10.5	12.5	12.8	13.1	14.2					
Hard Federation	Flour	10.5	12.6	13.0	13.4	14.1					

Summary and Conclusions

1. Variety, time, temperature, and size of kernel are all factors which affect the amount and rate of absorption of water by wheat, when immersed in water.

2. The rate and amount of absorption is increased when the outer bran coat is broken by the process of scouring. This increase is proportional to the scouring effect on the kernels.

3. Size and condition of kernel are of more importance than variety in the case of samples that are immersed.

4. Percentage of protein has very little effect on water absorption.

5. Water penetrates the bran and is distributed throughout the endosperm very rapidly. However, there are certain definite changes, necessary to proper conditioning, that take place after several hours of tempering.

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A CHEMICAL STUDY OF RANCIDITY

I. AUTOXIDATION OF SHORTENINGS AND CRACKERS¹

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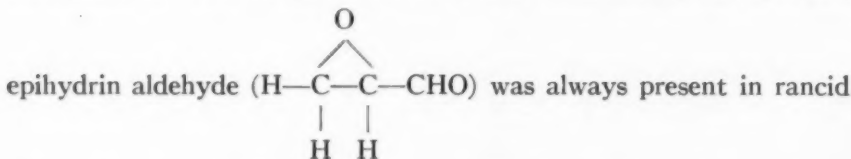
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Introduction

One of the important problems of the cracker baker involves the deterioration of crackers through oxidative rancidity. Since this deterioration is intimately connected with the autoxidation of the shortening in the crackers, the study of these materials becomes necessary.

No systematic research work has been published on the rancidity of crackers, although the literature of the oxidative rancidity of fats is fairly extensive. The existing knowledge of fat rancidity thus constitutes the starting point for the study of the rancidity problems of the cracker baker. One of the main objects of this investigation, therefore, was the development and application of methods for studying the autoxidation of crackers. Through this study it was anticipated that some practical information might be secured to aid in the production of crackers with better keeping qualities.

A partial review of the literature has been included in a previous paper by Triebold (1931) and will not be repeated here. It will suffice to indicate that, according to Ritsert (1890), Scherer, in 1795, first suggested that rancidity is a chemical process involving the addition of oxygen to the fat. This opinion was substantiated by the investigations of Ritsert (1890) on lard, Browne (1899), and Kerr (1918) on butterfat. Powick (1923) found that an oxidation product of fat,



fats, while the controlled oxidation studies by Holm and Greenbank (1923) show clearly the similarity between the autoxidation of fats and

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rancidity development. Oxidative rancidity thus involves the addition of oxygen to the fat, followed by a decomposition into characteristic end-products.

Materials

Cracker samples and the shortenings used in their production were obtained from various cracker factories. The crackers were shipped in commercial paper cartons while the shortenings were usually sent in glass containers, and in a few instances, in metal containers. In the latter event, the outer part of the shortening in contact with the metal was immediately removed and the central portion placed in a glass container. The shortenings were stored in a refrigerator and subjected to the various studies as promptly as possible.

Shortenings and crackers used in the development of the oxidation methods and for certain storage experiments were secured directly from the manufacturing plants. In this way, samples of a definite type and grade and of a uniform age were obtained.

Method for Making Oxidation Studies on Shortenings

Various methods have been used to study the oxidation of fats and from these the controlled oxidation method of Holm and Greenbank (1923) was selected as the most promising. A diagram of the apparatus² used in the method, modified slightly from that of Holm and Greenbank's, is given in Figure 1. The gas-tight stirrer was similar to that described by Holm and Greenbank (1923a), except that the glass stirrer was attached to the metal rod by a heavy piece of suction tubing thoroughly coated with Bakelite varnish. This permitted the expansion of the metal rod within the glass stirrer without shattering the stirrer. A cardboard disc coated with Bakelite varnish was attached to the stirrer so that it rotated at the lower end of the neck of the Kjeldahl flask and thus prevented the spattering of the fat up along the stirrer where some of it would come into contact with the metal parts and run back to act as catalyst in the oxidation. An effective seal was made between the glass container and the bushing of the stirrer by wrapping a piece of dental rubber around the point of junction and fastening it with a piece of friction tape. The measuring device consisted of a gas burette of 1000 cc. volume connected to an upright tube for leveling purposes.

The following is a detailed description of the procedure used for the oxidation of shortenings: 200 grams of shortening was weighed directly into the container. The stirrer was sealed to the flask, and the temperature of the water thermostat brought to 95° C. Oxygen from a cylinder was run through the entire system from 4 to 5 minutes

to insure the replacement of the air by oxygen. Equilibrium within the system was soon attained, the excess pressure being equalized by opening the tube to the atmosphere. The time elapsing before the first absorption of oxygen took place was noted and readings taken at 15 or 30 minute intervals thereafter of the volume of oxygen absorbed.

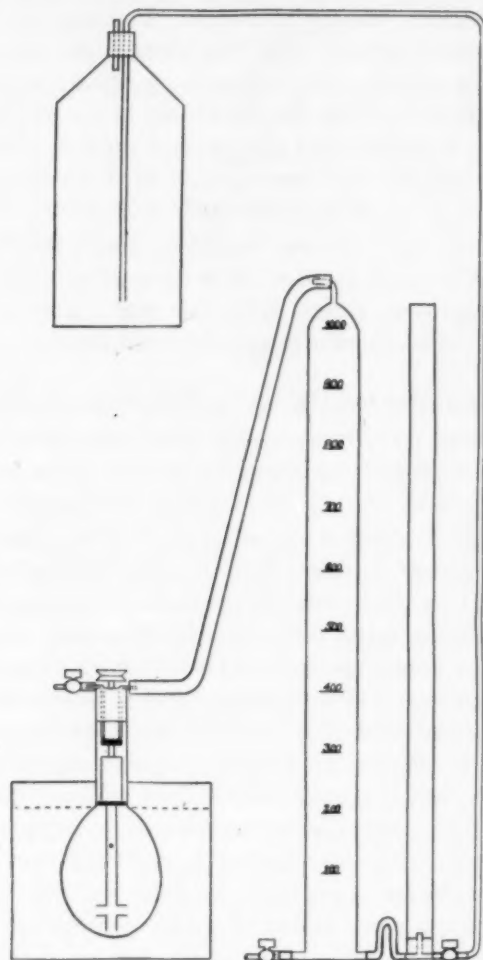


Fig. 1. Diagram of the apparatus used for the oxidation of fats, with stirring, at 95° C.

Induction Period of Oxygen Absorption of Shortenings

The length of time a shortening is in intimate contact with oxygen before any consistent and measurable absorption takes place is referred to as the induction period. This period may be accounted for on the basis that a certain oxidizing potential must be built up before the fat will oxidize. Holm, Greenbank, and Deysher (1927) believe

that loose oxygen combinations of potential oxidizing ability, or moloxide compounds, are the initial products formed upon the oxidation of unsaturated compounds. It may be assumed then, that the induction period of a fat consists of the time required to build up enough of these moloxide compounds to catalyze the reaction to the point where the absorption of oxygen becomes great enough to be measured.

Holm and his co-workers have found the length of induction period of oxygen absorption of a fat to be a relative measure of the keeping quality of the fat. The work of these investigators was done largely on butterfat so that a study to include all the shortening agents was deemed desirable. In such a study, it was found that samples of a particular type and grade of fat, of approximately the same age, and having the same history, would in general show comparable induction periods. This indicated that the induction period was influenced by the constitution of the fat, as should be expected, since the highly unsaturated glycerides should absorb oxygen more readily. Individual samples of a type of fat, however, may exhibit considerable differences in the lengths of induction period depending upon their age and past treatment, and since these two factors are largely responsible for the keeping quality of a type of shortening, a measure of the induction period should be a good index of keeping quality.

Development of a Static Oxidation Method for Crackers

A modification of the Holm and Greenbank stirring method for the oxidation of fats was made by Greenbank and Holm (1925), which permitted the oxidation of materials containing fats as well as the fats themselves. In this method the stirrer was dispensed with, the sample being simply exposed to oxygen in a closed system at a temperature of 70° C., and the induction period of oxygen absorption determined automatically. This method was applied by us to the determination of the length of induction period and rate of oxygen absorption of crackers. Some difficulty was experienced in the application of this method because of the need of a constant temperature thermostat with fine temperature control. In the original apparatus of Greenbank and Holm, this was not so necessary, since their automatic recording device could be regulated so that slight changes in temperature did not influence the readings obtained. The correct temperature control was effected by using a sensitive gas-mercury thermoregulator.

The apparatus and procedure adopted was as follows: A 100 gram sample of crackers was ground to a meal by means of a mortar and pestle, and dried for 5 hours at 70° C. in an electric drying oven. The sample was then transferred to a 500 cc. Erlenmeyer flask and tightly

stoppered with a rubber stopper carrying two glass tubes. The flask was placed in the thermostat at 90° C. and connected by means of heavy walled suction tubing to an inlet tube from the gas burette and to an outlet tube, opening through a stopcock, on the top of the thermostat. Oxygen from a tank was allowed to flow through the system for 4 minutes to insure the replacement of the air by oxygen. Approximately 90 minutes was required for the system to come to equilibrium after being filled with oxygen and the decrease in pressure within the system, considered as cc. of oxygen absorbed, was determined at hour intervals.

The oxidation data on two cracker samples studied by this method are given in Table I. Both samples appeared to start absorbing oxy-

TABLE I
VOLUME OF OXYGEN ABSORBED BY 100 GRAM SAMPLES OF DRIED CRACKERS OXIDIZED BY THE STATIC METHOD AT 90° C.

Time	Cracker sample 1		Cracker sample 2	
	Oxygen absorbed per 100 gram sample	Rate at which oxygen was absorbed at one hour intervals	Oxygen absorbed per 100 gram sample	Rate at which oxygen was absorbed at one hour intervals
Hours	cc.	cc.	cc.	cc.
2.0	0.0	0.0	0.0	0.0
3.5	0.3	0.3	0.2	0.2
4.5	1.3	1.0	1.1	0.9
5.5	2.6	1.3	2.3	1.2
6.5	4.4	1.8	3.5	1.2
7.5	6.8	2.4	4.7	1.2
8.5	10.0	3.2	6.1	1.4
9.5 ¹	1.0	1.0	0.0	0.0
10.5	8.7	7.7	0.0	0.0
11.0	15.3	6.6	0.3	0.3
12.0	35.5	20.2	2.0	1.7
13.0			5.0	3.0
14.0			8.5	3.5
15.0			13.7	5.2
16.0			19.7	6.0

¹ First reading for the second day's exposure of the samples to oxygen at 90° C.

gen at the same time, and this peculiarity was observed in practically all the cracker samples oxidized by this method. While two samples of crackers might show a similar oxygen absorption, it would not be expected that all cracker samples should behave the same, since the fats contained in the crackers are the substances oxidized, and these fats have different oxygen absorptions.

We must consider, however, that in the oxidation of crackers, both the wheat oil in the cracker flour and the added shortening are

subject to oxidation. It is doubtless the oxidation of the wheat oil, rich in unsaturated glycerides, which causes all crackers to start absorbing oxygen at approximately the same time, and it is only when the added fat begins to absorb oxygen, that the rate of absorption increases consistently. The end of the induction period for the cracker samples was considered as the point where the added fat began to be oxidized, that is, the point at which the rate of oxygen absorption began to increase regularly.

Application of the Static Oxidation Method to Fats

While the static oxidation method was developed especially for determining the length of induction period and oxygen absorption of crackers, it was also used for a similar study on fats. Under these conditions, the size and shape of the container used determined the amount of the fat sample in contact with the oxygen, and so, beyond a certain point, conditioned the rate of oxygen absorption by the sample. Smaller amounts of fat samples could be used, only enough fat being necessary to form a layer over the bottom of the container.

A sample of fat weighing 20 grams was placed in a 500 cc. Erlenmeyer flask, which was tightly stoppered with a rubber stopper carrying two glass tubes, and connected up in the thermostat in the same manner as for the oxidation of crackers. The flask and contents were allowed to stand in the thermostat for 30 minutes to attain the same temperature (90° C.), after which oxygen was run through the system for 4 minutes to replace the air. Equilibrium in pressure was reached within an hour after the replacement of air by oxygen. The rate of oxygen absorption by fats with the static oxygen method was not as great as by the stirring method, since in that method more surface and also a constantly new surface of fat was being brought into intimate contact with oxygen.

Length of Induction Period and Rate of Oxygen Absorption for Various Types of Commercial Shortenings

Samples of various types and grades of shortenings were examined by the stirring oxidation method and the lengths of their induction periods determined. These results are illustrated graphically in Figure 2. Since the comparison is between types of shortenings produced under the best of conditions, the length of the induction period of oxygen absorption should represent only the general length for a type, and should be dependent upon the constitution of the glycerides of that type of shortening.

Assuming that the length of the induction period represents the susceptibility of a shortening to oxidative rancidity, maize oil, cotton-

seed oil, and compounds exhibit the poorer keeping qualities; prime steam lard slightly better, with open kettle lard still better; all-hydrogenated shortenings and oleo oils very good, and coconut oil probably the best of all. This order of arrangement is what would be expected on the basis of the unsaturation of the fatty acid glycerides and is, in general, what has been found true in practice.

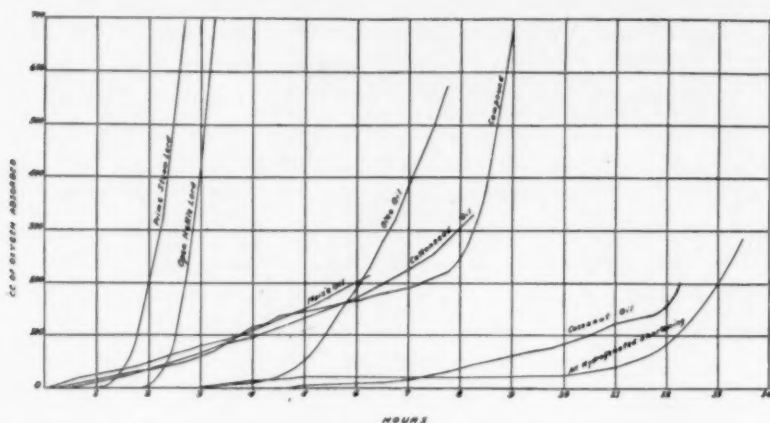


Fig. 2. The cc. of oxygen absorbed by 200 gram samples of various types of commercial shortenings, oxidized by the stirring method at 95° C.

When studying the keeping quality of a shortening, the rate of oxygen absorption is also considered along with the length of induction period. There is a great deal of difference in the rate of oxygen absorption by the various shortening samples in Figure 2. The absorption of oxygen by animal shortenings like lard, oleo oil, and butterfat, appears to be an autocatalytic process whereas vegetable fats such as maize oil, cottonseed oil, hydrogenated cottonseed oil, and coconut oil, exhibit a comparatively long period of slow oxygen absorption before the reaction reaches the autocatalytic stage. The occasion for this difference in the rates of oxygen absorption between such animal and vegetable shortenings has not been disclosed.

Holm, Greenbank, and Deysher (1927) found that the addition of acids to cottonseed oil did not catalyze the oxidation reaction nearly so greatly as in the instance of a similar treatment of butterfat. They explain this by stating that the course of the oxidation where two double bonds exist is not analogous to that where one double bond exists. This is no doubt true, and we should ordinarily expect a greater reactivity and oxidation in the compounds containing two double bonds such as linolic acid and its glycerides than in those containing one double bond. That this does not occur is very likely due to the fact that shortenings which are high in two double bond

glycerides are all vegetable shortenings and contain a substance which appears to inhibit the rate of the oxidation reaction. The substance which acts as an inhibitor is thought to be a hydroxy compound. Ricinoleic acid was found to be but slowly oxidized by Holm, Greenbank, and Deysher (1927), and castor oil, containing ricinoleic acid glycerides, was also found to be only slowly oxidized. Mattill (1927) found that wheat germ oil, which is high in hydroxy groups, delayed the progress of rancidity, and this observation was extended by Mattill and Crawford (1930) to show that sterols present in vegetable fats act as negative catalysts and lengthen the induction period of oxygen absorption of vegetable fats.

Oxidation Studies on Shortenings in Relation to the Keeping Quality of the Shortenings and the Crackers Produced

In agreement with the results of Holm, Greenbank, et al., (1923, 1924, 1925, 1927) there was found to be a general relationship between the length of induction period of a type of shortening and its recognized keeping qualities. This relationship appeared to be established in the instance of butterfat and lard, but is not so evident in some of the other shortenings such as oleo oil and the vegetable shortenings (cottonseed oil, maize oil, compound, and all-hydrogenated shortenings). Oleo oil shortenings exhibit a comparatively short induction period and yet have very good keeping qualities. The vegetable shortenings (maize oil, cottonseed, oil and compound) have short induction periods but differ some in rate of oxygen absorption which appears to bear a relationship to their keeping quality. This also holds true for the all-hydrogenated shortenings, and their good keeping qualities can be explained to some extent, at least, by their slow rate of oxygen absorption. There is then, in general, a relationship between the length of induction period, or length of induction period plus rate of oxygen absorption, and the keeping qualities of shortenings, although in some types of shortenings this relationship is more definite than in others.

In order to have any practical significance there was still the necessity of determining how close a relationship could be expected between the length of induction period of a shortening and the keeping quality of the crackers made from that shortening. To make a study of this, two series of cracker samples with the shortenings used in them were secured from a number of commercial cracker bakeries. In Series 1 (Table II) the shortenings were oxidized by the stirring method at 95° C., and in Series 2 (Table III) by the static oxidation method at 90° C. Rancidity in the crackers was determined by the detection of a rancid odor upon storage at either 40° C. (Series 1), or at room temperature (Series 2).

TABLE II

LENGTH OF INDUCTION PERIOD OF SHORTENINGS IN RELATION TO THE KEEPING QUALITIES OF CRACKERS PRODUCED FROM THE SHORTENINGS

Series 1

Sample number	Type of shortening	Length of induction period in hours (Oxidation of 200 grams of shortening by the stirring method at 95° C.)	Days until rancid odor developed in crackers stored at 40° C.
26	All-hydrogenated	3.50	87
29	All-hydrogenated	3.25	87
2	All-hydrogenated	2.75	87
7	All-hydrogenated	2.00	77
18	All-hydrogenated	4.75	49
8	All-hydrogenated	1.00	41
21	Compound	0.50	41
30	Compound	0.50	28
17	Open kettle lard	5.00	72
25	Prime steam lard	4.50	49
9	Prime steam lard	3.00	49
4	Prime steam lard	0.75	45
10	Open kettle lard	3.00	41
24	Open kettle lard	2.25	41
15	Prime steam lard	2.25	37
13	Open kettle lard	1.75	37
12	Prime steam lard	2.00	28
6	Prime steam lard	0.75	28
27	Prime steam lard	3.50	23
16	Prime steam lard	1.50	23
28	Open kettle lard	3.50	18
1	Open kettle lard	1.25	18
19	Prime steam lard	0.50	18

In each series, the data indicate somewhat of a relationship between the length of induction period of the shortenings and the keeping quality of the resulting crackers, especially within a certain type, but the correlation is far from what could be desired. Absolute agreement, of course, could not be expected since the factors involved in the manufacture of the crackers should influence the keeping qualities somewhat, and for this reason there are in each series of crackers, samples which show much better or poorer keeping qualities than the lengths of the induction periods would seemingly warrant.

Crackers produced from shortenings 28, 27, and 18 (Table II), and sample 5960 (Table III) exhibit much poorer keeping qualities than the lengths of their induction period would indicate. This might be explained on the basis that some part of the manufacturing process exerted a detrimental effect upon the keeping quality of the shortening in the cracker. The behavior of samples 4 and 6 (Table II), however, is not so easily explained since the crackers had good

TABLE III
LENGTH OF INDUCTION PERIOD OF SHORTENINGS IN RELATION TO THE KEEP-
ING QUALITIES OF CRACKERS PRODUCED FROM THE SHORTENINGS

Series 2

Sample number	Type of shortening	Length of induction period in hours (Oxidation of 20 grams of shortening by the static method at 90° C.)	Days until a rancid odor developed in crackers stored at room temperature
5954	All-hydrogenated	—	Sweet at end of 833
5956	All-hydrogenated	39.50	Sweet at end of 833
5957	All-hydrogenated	32.50	729
5955	All-hydrogenated	23.00	729
5990	Oleo oil	3.50	705
5988	Open kettle lard	1.00	692
5962	Open kettle lard	1.25	473
5967	Open kettle lard	5.75	458
5961	Prime steam lard	3.25	320
5958	Prime steam lard	3.25	214
5959	Prime steam lard	2.75	112
5960	Prime steam lard	2.00	30

keeping qualities although the shortenings used had short induction periods. This same behavior was noted in samples 5988 and 5962 (Table III). The only explanation which is suggested for these results is that some substance is added to, or, produced in the manufacture of the crackers which slows up the development of rancidity in the shortening contained. There is a possibility that wheat oil contained in the cracker flour might act in this manner although Wesson (1924) considers wheat oil as a factor in aiding the development of rancidity in baked goods, rather than as a preservative against rancidity.

No reasonable explanation can be offered for the peculiar behavior of shortening sample 5954 (Table III) when oxidized. This sample turned brown almost immediately upon being exposed to oxygen at 90° C., but did not acquire a rancid odor or give a positive Kreis test after 130 hours exposure to oxygen at 90° C. During this long period of oxidation, this shortening exhibited practically no oxygen absorption until after 86 hours exposure, and from then on an irregular absorption until the experiment was discontinued at the end of 130 hours.

**Keeping Qualities of Crackers Compared with the Length of Their
Induction Periods and with the Length of Induction Periods of
the Shortenings Used in Them**

It has been previously indicated that there is a relationship between the length of induction period of a shortening and its keeping

quality, and also to a lesser extent, to the keeping quality of the crackers in which it was used. This lack of agreement between the length of induction period of shortenings and the keeping quality of the resulting crackers has been laid to the effects produced in the shortenings when manufactured into crackers. If the length of induction period of crackers themselves could be determined it would take into account the effects of manufacture and should give a true representation of keeping quality. The results of such a study are summarized in Table IV.

TABLE IV

THE KEEPING QUALITIES OF CRACKERS IN RELATION TO THE LENGTHS OF INDUCTION PERIODS OF THE CRACKERS AND OF SHORTENINGS USED IN THEIR PRODUCTION

Sample number	Type of shortening	Length of induction period in hours (20 grams of shortening oxidized by the static method at 90° C.)	Length of induction period in hours (100 grams of crackers oxidized by the static method at 90° C.)	Days until a rancid odor developed in crackers stored at room temperature
5954	All-hydrogenated	—	32.50	Sweet at 833
5956	All-hydrogenated	39.50	31.50	Sweet at 833
5957	All-hydrogenated	32.50	23.25	729
5955	All-hydrogenated	23.00	24.00	729
5990	Oleo oil	3.50	31.50	705
5988	Open kettle lard	1.00	17.50	692
5962	Open kettle lard	1.25	10.75	473
5967	Open kettle lard	5.75	11.00	458
5961	Prime steam lard	3.25	3.50	320
5958	Prime steam lard	3.25	3.00	214
5959	Prime steam lard	2.75	2.50	112
5960	Prime steam lard	2.00	0.50	30

A much better correlation was found to exist in all cases between the lengths of induction periods of crackers and their keeping quality, than between the lengths of induction periods of shortenings and keeping quality of the crackers. If the various cracker samples are arranged in the order of the lengths of their induction periods, as in Table IV, it will be seen that with one or two minor exceptions, this is exactly the order of their keeping qualities at room temperature.

Another interesting fact is that the cracker sample produced from oleo oil shortening had the length of its induction period approximating those of the cracker samples made from the all-hydrogenated shortenings. This also indicates more truly the keeping quality of the

crackers, since crackers made from oleo oils have always been found to have as good or superior keeping qualities to those made from all-hydrogenated shortenings. Theoretically, that is what would be expected on the basis of the type of unsaturated glycerides found in the shortenings since both have their unsaturated glycerides practically entirely derived from oleic acid. The induction period of the oleo oil shortening places the shortening in the same class with the lards and gives no idea whatsoever as to the good keeping quality of the crackers.

The rates of oxygen absorption by three cracker samples and the lard shortenings used in their production are represented in Figure 3.

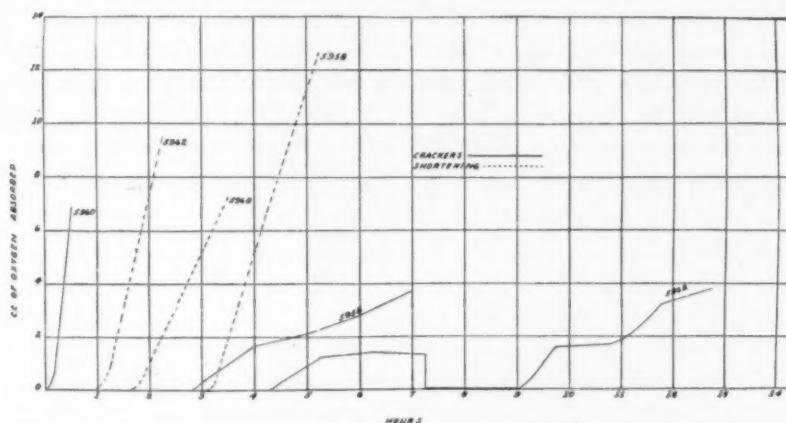


Fig. 3. Rate of oxygen absorption by samples of shortenings and crackers produced from them. The cc. of oxygen absorbed represents the amount of absorption for one hour intervals by 20 gram samples of shortenings, and 100 gram samples of crackers, oxidized by the static method at 90° C.

It is evident from this graph that the length of induction period and the rate of oxygen absorption of the crackers gives a much better representation of their keeping quality than the length of induction periods of their shortenings alone. Cracker sample 5960 immediately showed a rapid rate of oxygen absorption which indicated exactly the keeping quality of the crackers, whereas the length of induction period of the shortening used indicated much better keeping quality. Evidently in the process of cracker production, the shortening received some treatment detrimental to its keeping qualities so that the resulting crackers had poor keeping qualities. The relatively long induction period of cracker sample 5962 indicated the good keeping qualities that were actually found, while the shortening used had a comparatively short induction period indicative of poor keeping qualities. Here it would appear that the process of cracker manufacture enhanced the keeping qualities of the shortening so that it exhibited better keeping qualities than before being made into crackers. Shortening

and cracker sample 5958 showed approximately the same length of induction period. Evidently, in this case, the shortening was not affected in the process of cracker manufacture and under these circumstances the length of induction period of the shortening is also an index of the keeping quality of the resulting crackers.

Correlation of the Keeping Qualities of Crackers with the Length of Induction Period of the Crackers or of the Shortenings Used in Their Production

It is evident from the data in Tables II, III, and IV, that there is a correlation between the length of induction period of a shortening and the keeping quality of the cracker in which it is used, but, that a better correlation exists between the length of induction period of a cracker and its keeping quality. To determine the degree of correlation, "coefficients of rank of correlation" were determined according to Jackson (1924), using the formula:

$$r = 1 - \frac{6\sum D_k^2}{n^3 - n},$$

and the probable error by the formula:

$$e = 0.706 \times \frac{1 - r^2}{\sqrt{n}}.$$

The "coefficient of rank of correlation" between the length of induction period of shortenings and keeping quality of crackers (Table II) was found to be $r = +.504 \pm .109$; between the length of induction period of shortenings and keeping quality of crackers (Table III) was found to be $r = +.805 \pm .071$; and between the length of induction period of crackers and their keeping quality (Table IV) was found to be $r = +.979 \pm .008$.

The fact that a closer correlation was evidenced between the length of induction periods of shortenings and the keeping quality of crackers in Table III, than in Table II, is probably due to the fact that the keeping quality of crackers can be more accurately determined at room temperature than when stored at 40° C., and also, that the determination of the length of induction period by the static method at 90° C. (Table III), presents less chances for error than the stirring method at 95° C. It is evident from the close correlation between the length of induction period of crackers and their keeping qualities that the length of induction period of crackers should be a very good index of their keeping quality.

Summary and Conclusions

Methods for making controlled oxidation studies at 90° C., have been adapted and applied to crackers.

Length of induction period and rate of oxygen absorption are given for the various shortening agents used in cracker manufacture.

Keeping quality of crackers was found to be generally related to the length of induction period of the shortenings used in them, but several outstanding exceptions to this relationship were noted. The coefficient of rank of correlation found for Series 1 was $+ .504 \pm .109$, and for Series 2 it was $+ .805 \pm .071$.

Keeping quality of crackers was found to be more closely related to the length of induction period of the crackers themselves. The coefficient of rank of correlation found was $+ .979 \pm .008$.

Acknowledgments

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BULLETIN REVIEW

Definitions and Standards for Food Products. (S. R. A., F. D. No. 2, second revision.) Food and Drug Administration. September, 1931.

This is the second revision of this publication. It brings up to date definitions and standards of a wide variety of foods and beverages. The publication is technical and designed for official use in enforcing the Federal food and drugs act. Definitions and standards given are those published in S. R. A., F. D. No. 2, Revision 1, and those issued as supplements 1, 2, and 3 to this announcement, and those adopted on June 17, 1931. The definitions are so framed as to include substances not mentioned in the definition and in each instance imply that the product is clean and sound. The latest official standards for a variety of animal and vegetable products, for beverages, salt, and baking powder are included in the publication.

Copies of the above publication may be obtained by writing to the Division of Publications, Office of Information, United States Department of Agriculture, Washington, D. C.

THE USE OF CERTAIN CONSTITUENTS IN BREADMAKING WITH PARTICULAR REFERENCE TO THE PROBLEM OF STALING¹

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(Read at the Convention, May, 1931)

Introduction

Davis and Eldred (1923) state that stale bread may amount to 2½ or 3 per cent of the total production. Before the war the percentage was even greater. According to the Bureau of the Census, over 10 billion pounds of bread were made in 1929. Pirrie (1931) states that 4.7 per cent of the bread produced in 1930 became stale. This means there were about 470 million pounds of stale bread last year. For every cent less than the price of fresh bread at which a loaf of stale bread is sold, the baking industry suffers a loss of over four and one-half million dollars. To eliminate as much as possible of this enormous economic loss is a worth while object.

Just when bread becomes stale has not been determined. President Stude of the American Bakers' Association stated in a private communication that, in his opinion, bread begins to grow stale the minute it has cooled; therefore, it is only a question of degree.

It is no doubt true, as experiments conducted by ourselves as well as by others show, that bread begins to change or grow stale immediately after baking. This, however, is hardly an answer to the question. Ordinarily bread is not considered stale by the trade the same day that it is baked, but is so regarded on the second day.

The exact changes that take place when bread becomes stale are not clearly understood. A theory has been advanced by Katz (1913) and modified by Ostwald (1919) to the effect that much of the moisture contained in bread is held by the starch which has been gelatinized in the baking. When the bread cools, the starch gives up some of its moisture which is absorbed by the other constituents, especially the coagulated gluten of the crumb. The crust changes from a harsh brittle material to a soft pliable one, and the crumb increases in firmness. It loses its tough elastic property and becomes crumbly.

If heat is applied to bread in this condition it again assumes the

¹ Food Research Contribution No. 110.

properties of fresh bread. This bread will again become stale upon standing and once more will return to the fresh condition upon the re-application of heat. This process has been repeated as many as seven times before the bread had lost so much moisture that reversal no longer took place. Because of these reversible changes in the bread it has been likened to the allotropic modifications of sulphur, and stale bread is considered the stable form at ordinary room temperature.

From experiments made, Katz concludes that above 140° F. bread retains its freshness entirely; at 104° F. it becomes half stale, at 86° F. still more so, and at 63° F. and 32° F. it becomes totally stale, while at still lower temperatures staleness is retarded. Thus, at 26° F. bread not only retains its freshness, but the aroma is better than when the bread is stored at room temperature or higher. Not only are there less volatile constituents given off at the lower temperatures, but bacterial development is arrested, and the production of bacterial odors which affect the flavor is held to a minimum.

Experimental Methods Used

Because of the importance of this subject, it was deemed desirable to give consideration to some of the conditions that govern staleness in bread and if possible find some substance that might be added to a bread dough that would in some degree retard staleness.

As one means of measuring staleness the compressibility test, which was described by the author at the Convention of the American Association of Cereal Chemists last year and published in *Cereal Chemistry* 7, 340-341, was employed, with the exception that a block weighing 500 grams was substituted for the 1000-gram block previously used.

That the change in firmness or compressibility of crumb (one means of measuring staleness) is gradual, is shown by the following results:

TABLE I
VARIATION IN DEPRESSION ACCORDING TO AGE OF BREAD

Age of bread	500-gram weight. Depression in 1 min. ¹
hours	mm.
1	37
2	37
3	36
4	35
5	35
6	35
8	35
10	34
12	34
14	33
16	31
18	30

¹ The prism of bread was 50 mm. in height before being depressed.

Peper (1926) gives a method for the determination of the age of bread which consists of kneading 20 gms. of crumb in water and brushing it through the meshes of a silk bolting cloth, placing the suspended bread in a 250 cc. graduated cylinder, making up to mark with water, adding a little toluene and allowing to settle 24 hours. The volume of sediment formed in the suspension depends on the specific gravity of the starch granules and permits estimation of the degree of syneresis. The test suffices to distinguish very fresh bread from bread more than 12 hours old.

Typical results by this method of testing are shown in Table II.

TABLE II
RESULTS OBTAINED BY USE OF THE PEPER TEST

Age of bread	Sediment
hours	cc.
Fresh	80
20	62
44	61
68	64
92	58

Whympers (1930) refers to this same characteristic of bread in one of his conclusions, viz., "The capacity of bread for swelling in water is considerably smaller when stale than when fresh."

Other changes in stale bread have been noted by Whympers, such as a fall in the soluble extract obtained from the crumb during the process of becoming stale, followed after a time by a rise. He also observes that the loss of water during cooling and drying out of a loaf is not responsible for staleness.

In our preliminary study of this subject we have depended mainly upon the depression of the crumb and the volume of the sediment to measure the degree of staleness. We have also made a few tests with soluble extract and soluble nitrogen.

Study of Materials for Use in Retarding Staling

In our quest for some substance that might be included in the dough mix which would have the effect of retarding staleness in the finished loaf as measured by compressibility and sedimentation, we naturally turned to those materials for which stale retarding properties have been claimed.

Dextrinized Starch. We first used a commercial preparation which is reputed to be a moisture retaining substance. This is essentially a dextrinized starch. Corn sugar was also used in comparison with cane sugar. Our experiments showed that these substances appear to have but little effect on retaining the freshness of the bread. When bread

was stored for 24 hours at 83° F. with a relative humidity of 88 per cent, the loss of moisture in the center of the loaf was slightly less in the case of the partially hydrolyzed starch, and the weight loss was slightly greater in the case of the corn sugar, while the depression caused by the 500 gm. weight was about the same in all cases. By the sedimentation test there was practically no difference in the breads when two days old

Invert Sugar. A commercial invert sugar was used in a similar manner, and this yielded practically no difference in the breads by any of the four tests. Honey gave essentially the same results.

Malt Extract. Malt extract was used in concentrations of 1, 2 and 3 per cent. This variation in concentration did not materially affect the keeping quality of the bread. In general, however, malt extract does have a retarding influence on staling as shown by the depression test.

Potato Flour. Home-made bread often contains either mashed potato or the water in which the potatoes were boiled. It is claimed that this makes a moist bread that keeps well. Bakers have available commercial potato flour. This was used in concentrations of 1½ and 3 per cent. The breads were stored in a cabinet for three days, at a temperature of approximately 75° F. and a relative humidity of about 85 per cent. The loaves made with 3 per cent potato flour had a little more moisture in the center of the loaf and the depression was somewhat greater than with 1½ per cent of potato flour, thus indicating that potato flour does exert an influence when judged by the compressibility test. The sedimentation test, however, showed no advantage due to the use of potato flour.

Sour Dough (lactic bacilli). A commercial preparation containing lactic acid bacilli was then used in making bread. With this product a dough was made by the addition of flour, potato flour, and water. This dough was allowed to stand over night for the development of the lactic acid organisms and then from 1 to 5 per cent of this sour dough was incorporated in test doughs containing 2 per cent of potato flour. By the compressibility test some improvement was seen with all of these additions; the maximum improvement shown was by the use of 3 per cent of the sour dough.

Dairy Products. These experiments were followed by a series of tests in which dairy products were incorporated. In these tests whole milk, skim milk, buttermilk, whey, cream, double cream, dry skim milk, and dry whey were used. We also used some milks that had been carefully heated, others that had been homogenized, and some that had been both heated and homogenized. None of these products delayed the staling as measured by the compressibility test. In fact,

the bread made with the double cream actually became stale more readily than the control made with water.

Protective Colloids. Since bread is a complex colloidal substance, it was thought that perhaps some protective colloid might be found that would definitely delay the normal period of staling. Accordingly we used agar, mayonnaise, and two commercial vegetable lecithins. None of these substances, except possibly the agar, produced any marked improvement in the keeping qualities of the breads as measured by the depression test.

Calcium Peroxide. Certain mixtures containing calcium peroxide are claimed to increase the water absorption of a flour, but it was not found that staling could be prevented by their use. In fact, as stated in the literature as well as shown by our experiments, staling is not dependent upon loss of moisture; for example, the moisture determined on a prism of bread taken from the center of a loaf was 43.6 per cent when the bread was fresh, 42.7 per cent in a duplicate loaf 20 hours old, and 42.1 per cent in another loaf 68 hours old. But this bread became stale in 20 hours as shown by the sedimentation and compressibility tests in Table III.

TABLE III
SHOWING RELATIONSHIP BETWEEN STALING AND PER CENT OF MOISTURE IN LOAF

Age of bread	Sediment	Compressibility	Moisture
hours	cc.	mm.	P.ct.
Fresh	80	41	43.6
20	62	32	42.7
68	64	18	42.1

Carbon Dioxide Gas. U. S. Patent 1,155,530 describes a process of keeping bread fresh by surrounding it with an atmosphere of carbon dioxide, containing, in addition, a flavoring material. It recommends the use of recently produced fermentation gases which contain delicate aromas of fermentation. This process was not checked; we did, however, pack fresh bread in solid carbon dioxide, and maintained it in a frozen condition in an atmosphere of carbon dioxide gas for two days. At the end of this period the bread was allowed to thaw out, when it had very much the appearance and characteristics of fresh bread. By the compressibility test it was almost the same as fresh bread.

Low Temperatures. The next nearest approach to fresh bread was obtained by storing bread for 3 days at a temperature of 15° F. The bread, of course, froze throughout, but upon gradually warming the thawed-out bread had much of the characteristics of fresh bread. Nevertheless, the depression of the crumb was 26 mm. while in a fresh loaf it is about 39 mm.

Elevated Temperatures. A more remote approach to fresh bread was obtained by storing the bread at 150° F. for 3 days. The crumb from the center of this loaf had a depression of 31 mm., but the flavor was not as agreeable as that of the bread that had been frozen. It is very difficult to keep the bread at this high temperature without its suffering loss from evaporation.

Wrapping Bread. Bread wrapped in waxed paper and stored for 3 days in an electric refrigerator at a temperature of about 45° F. became quite stale, as indicated by the depression test. The depression was only 7 mm. as compared with 26 mm. when stored at 15° F.

Conclusions

A preliminary study has been made of the influence of the use of certain constituents in bread-making from the standpoint of preventing, or at least retarding, the development of the condition known as staleness. While a few of the substances seemed to retard this condition slightly, none of them produced the results desired. Rather interesting observations were made by keeping bread at a temperature below freezing and allowing it to thaw out gradually, when it exhibited some of the characteristics of fresh bread.

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EFFECT OF PLANT NUTRITION ON THE COMPOSITION OF WHEAT ¹

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(Read at the Convention, May, 1931)

Introduction

It has been recognized for a long time that various sections of the world produce wheats of widely different milling and baking qualities. In certain sections typical hard wheats of high protein content and superior baking strength are produced which are especially well adapted for making bread. In other areas softer wheats of lower protein content and baking strength are grown which are better suited for making crackers, cakes, or biscuits. It is generally believed that these variations in baking quality may be accounted for on the basis of differences in the chemical and physical properties of the wheats. The factors responsible for these differences in quality are numerous and complex. It is difficult to correctly evaluate the part played by any one factor.

For convenience we may separate the factors into two categories, first, genetical factors; and second, environmental factors. While the differences in quality of wheat may be explained, in part, on a genetical basis, that is, by the different varieties grown, it has been demonstrated conclusively that environmental factors are very important. The capacity of a given variety to produce wheat of a certain composition is fixed within certain wide limits by its genetical constitution. Within these limits quite wide differences in composition may be obtained depending upon the environment under which the plant is placed. In our present discussion we are interested primarily in the second group of factors, namely, the environmental effects. However, it may be of interest first to consider briefly the changes occurring in the development of the wheat kernel.

Development of the Wheat Kernel

Many early workers, on the basis of analyses showing a decrease in percentage of nitrogen and an increase in percentage of carbohydrates as the wheat kernel matured, concluded that during the later stages of

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development, carbohydrates were moved into the grain in larger quantities than nitrogenous materials. Brenchley and Hall (1909) made a very intensive study of the progressive changes in the development of the wheat kernel, from the morphological, as well as chemical standpoint. They conclude that: "For the filling of the endosperm each plant possesses as it were a special mould, and continually moves into the grain uniform material cast in that mould, possessing always the same ratio of nitrogen, to non-nitrogenous materials and ash. The character of the mould possessed by each plant is determined by variety, soil, season, etc."

The results of Brenchley and Hall were contradictory to the previous conceptions and this prompted Thatcher (1913, 1915) to carry out similar experiments at the Minnesota Experiment Station. His results showed that the actual amounts of protein, starch, pentosan, fiber, ether extract, and ash increased regularly throughout the period of kernel formation but that the carbohydrate increase was relatively the largest for the total period.

Woodman and Engledow (1924) recently made a very thorough study of the changes that occur in the progressive development of the wheat kernel. They found, in agreement with Brenchley and Hall, that the development of the grain may be divided into three growth periods: (1) Up to 40 days after head emergence the water content of the grain increases; (2) from 40 days to 50 days the water content remains roughly constant; and (3) from 50 to 65 days a marked desiccation occurs. The fresh weight of the kernels increases continually until the 50th day and then diminishes. The actual dry weight of the grain increases rapidly until the 50th day and then very little change occurs. The period of desiccation, from the 50th to 65th day, is marked by desiccation and is not accompanied by transportation of fresh material into the grain. There is a gradual increase in amount of total nitrogen and protein nitrogen until the 50th day, and of non-protein nitrogen until the 47th day, after which there is little change in amount of total nitrogen. From the 50th to the 54th day there is an increase in protein and a corresponding decrease in non-protein nitrogen. The first distinct signs of gluten formation occur at the 50th day with the beginning of desiccation when the percentage of gliadin has risen to 0.79 % and the glutenin to 0.58 %. After this the percentage of gliadin nitrogen rose to 1.02 % while the percentage of glutenin remains about constant. The authors believe that the presence of a definite amount of glutenin is necessary before gluten formation is possible. The amount of ash increases until the period of desiccation and then remains about constant indicating that transportation of inorganic materials into the grain ceases at the beginning of the period

of desiccation. Carbohydrates increase rapidly until the 50th day when desiccation sets in and then remain about constant. Apparently translocation of materials into the grain ceases at the beginning of desiccation.

Olson (1917) found no gluten present in the early stages of the development of the kernel. Gluten first appeared at the time when translocation fell off rapidly and desiccation set in. Eckerson (1917) noted that protein, having the properties of gluten, appears in the storage cells of the grain when desiccation occurs.

Effect of Nutrition on the Composition of Wheat

The nutrition of the wheat plant is determined largely by its environment which consists of such factors as the climatic factors including total annual amount and seasonal distribution of rainfall, sunshine, temperature, etc.; the type and composition of the soil; cultural methods and fertilizers applied. These factors are difficult to study experimentally due to the lack of means of controlling the factors. Nevertheless much valuable data have been accumulated concerning the effect of environmental factors on the composition of wheat. Differences in the protein contents of wheats have received most attention. In general, starch content is in inverse relation to the protein. Interpretation of the data regarding the effect of environmental factors on the composition of wheat has frequently indicated conflicting results.

On the basis of our knowledge of the progressive changes occurring during the development of the wheat kernel, it seems possible to suggest a tentative principle pending more definite experimental proof which may aid in the interpretation of this problem. It is suggested that the protein content of the mature grain will depend upon the relative amounts of carbohydrates and nitrogenous compounds made available to the developing grain during the period of translocation.

For the purpose of considering the effect of nutrition on the composition of wheat we may divide the growth period of the wheat plant into three periods: (1) The vegetation period extending until head emergence; (2) the period of translocation of elaborated materials into the kernel; and (3) the period of desiccation.

Conditions favoring a relative abundance of carbohydrates compared to nitrogenous material during the translocation period will result in low protein wheat. On the other hand, conditions resulting in a less abundant supply of carbohydrates compared to the nitrogenous materials will result in a high protein wheat. It is possible that the immature seed in its earlier stages may be relatively higher in protein compared to the materials translocated into the developing seed. If

this is true, conditions which shorten the period of development should lead to higher protein contents of the grain. On this basis, the effect of long periods of growth after heading time in favoring well developed kernels high in starch and low in protein is easily explained. Long periods of growth after heading result in a greater opportunity for photosynthesis and the accumulation of relatively greater amounts of carbohydrates in relation to the available nitrogenous compounds resulting in grain of low protein content.

Exact information is not available as to the point of development at which the wheat plant is no longer able to utilize inorganic nitrogen in the synthesis of organic nitrogenous compounds. The work of Woodman and Engledow (1924) shows definitely that translocation of substances into the kernel ceases with the onset of desiccation. Studies by Davidson and LeClerc (1917) on the effect of the application of nitrogenous fertilizers on the protein content of wheat show that the application of sodium nitrate at the time of heading increases the protein content of the grain markedly, but that applications at the milk stage result in only a slight increase in protein content of the grain. These results would indicate that the wheat plant does not absorb and utilize inorganic nitrogen to any extent after it has reached the "milk" stage in the development of the kernel. On the other hand, we know that the synthesis of carbohydrates will continue as long as the leaves contain chlorophyll and that they may be translocated into the kernel until the stage of desiccation sets in. Short periods of growth after heading should then result in less opportunity for carbohydrate accumulation in relation to the available nitrogenous compounds and yield a wheat of high protein content. It is interesting to review the results of experience in the light of this hypothesis.

Effect of Climatic Factors on Composition of Wheat

Early observation of marked variations in protein content of the same variety of wheat when grown in various localities raised the question as to whether the differences were due to climatic factors or differences in soils. Lawes and Gilbert (1884) believe that a season favorable for long and continuous growth after heading time produces large yields and well developed kernels, which are high in starch and low in protein, potash, and phosphoric acid. Wiley (1899) concluded that cool climates and short periods of growth favor high protein, while warm climates and long periods of growth favor low protein contents of wheat. Jensen (1901) believes that a continental climate is favorable to the formation of small grain with high nitrogen content.

LeClerc (1910) conducted extensive studies to determine the influence of climate, soil, and seed on the composition of wheat. Wheat

from the same original seed was grown in Kansas, Texas, and California. Three plots were grown at each station; one plot was grown continuously at each station and the seed of the other plots was from the other stations. The original Crimean wheat grown in Kansas in 1905 contained 16.2 % protein. In 1907 the three plots of wheat grown in Kansas had the following protein contents respectively, 22.2 %, 22.2 %, and 22.8 %; those grown in Texas contained 18.2 %, 17.0 %, and 18.2 % and those grown in California 11.3 %, 11.0 %, and 11.4 %. LeClerc concluded that these differences were due mainly to climatic conditions prevailing at the time of growth. The experiment did not entirely eliminate the possibility of soil effects. In a later experiment LeClerc and Yoder (1914) attempted to eliminate the soil factor. Soil from California was transferred to Maryland and Kansas; soil from Kansas was transferred to California and Maryland, and soil from Maryland was transferred to California and Kansas. In 1910, 1911, and 1912 the protein content of the wheat grown in California was uniformly low, about 13.0 %. In Maryland it was also low, about 11.0 %, while in Kansas it was high, nearly 18 %. If the data are arranged in accordance with the source of the soils the wheats grown on California soil in the three localities averaged 13.88 % protein, those on the Kansas soil 13.94 %, and those on the Maryland soil 15.44 %. These results demonstrate definitely the effect of climatic conditions on the protein content of wheat.

Climatic factors such as temperature, rainfall, etc. through their influence on the soil will also affect the supply of nitrogen available to the plant. Widstoe and Stewart (1912) found that the protein content of wheat decreases with increased amounts of irrigation water. Kezer (1926) observed that application of irrigation water at the time of heading and blossoming results in a lower protein content of the grain. It is commonly believed that abundant rainfall during the period from heading to maturity results in a lower protein wheat. The application of irrigation water or abundant rainfall at this period would be expected to reduce the available supply of nitrate nitrogen to the plant as a result of leaching. Such conditions should result in a relatively larger carbohydrate supply in relation to the nitrogenous compounds available for translocation into the developing wheat kernel and may be expected to yield grain of a low protein content. In this connection some very interesting observations were reported by Thatcher (1909). He points out that in Washington fall sown wheats of any particular section are usually lower in protein and higher in starch than spring sown wheats. The spring sown wheats usually ripen at a later period when the temperatures are higher and the period of maturation is shorter. During the summer of 1907 in Washington, however, the

first two weeks of July were usually hot and dry and as a result the fall wheats matured very rapidly. This was followed by five weeks of cool, cloudy weather resulting in a very slow period of ripening of the spring sown grain. An analysis of 320 samples of fall wheats showed an average protein content of 14.59 % while a similar number of spring grown wheats averaged only 7.52 % of protein. This was a complete reversal of the usual situation.

From analyses of 456 samples of wheat grown in the state of Washington under conditions of uniform soil, growing season, distribution of annual rainfall, and elevation, Thatcher (1911) found that the protein content varied inversely with the total rainfall.

From a study of the analyses of wheat crops, in 1921, 1922, 1923, and 1924, Mangels (1925) found no correlation between the protein content and total rainfall. However, high temperature characterized the months of June and July in 1921 and 1923 when the protein content was high, while low temperature prevailed during the same period of the years 1922 and 1924 when low protein wheats were produced.

Effect of Nitrogen Fertilizers

During recent years numerous studies have been made to determine the effect of top dressing with nitrogen salts on the protein content of wheat. Davidson and LeClerc (1917, 1923) applied sodium nitrate at the rate of 320 pounds per acre to various plots of both hard and soft wheat at each of the following stages: (1) When the wheat was two inches high; (2) at the time of heading; and (3) at the milk stage of the kernels. Nitrogen applied at the first stage resulted in an increased yield but only a very slight increase in protein content. Nitrogen applied at the second and third stages showed no increase in yield. The plots receiving nitrogen at the time of heading showed a marked increase in percentage of protein while those receiving nitrogen at the milk stage showed only a slight increase in protein content. Those receiving applications of nitrogen at both the second and third stages showed a distinctly higher protein content of wheat than those receiving applications at the first and the second stages. In later experiments Davidson (1922) applied nitrates at the following three dates: April 11th, April 24th, and May 14th. These data show very strikingly that the effectiveness of nitrates in increasing yields gradually decreases as the time of application approaches the heading period. On the other hand, the protein content of the grain increases regularly as the time of application advances towards the heading period. He concludes that the effectiveness of nitrates in increasing the protein content of the grain increases as the effectiveness in increasing the yield decreases. Gericke (1920, 1922) applied sodium nitrate at vary-

ing number of days after planting and found a gradual increase in protein content of grain with an increased length of time after planting that the nitrate was applied.

Neidig and Snyder (1922) carried out extensive field and greenhouse studies to determine the effect of available nitrogen on the protein content and yield of wheat. They found that when there was a sufficient amount of available nitrogen present in the soil during the early periods to result in maximum growth of the plant a high yield was obtained. When the nitrogen of the soil was sufficient to insure a good supply during the later life cycle of the plant both a high yield and high protein were obtained. They believed that both climate and available nitrogen are important in determining the protein content of the grain. If an ample supply of nitrogen is available they believe that moisture is the chief climatic factor affecting the yield and protein content of wheat.

Gericke (1927a) compared the effect of applications of nitrogen at time of planting and 30 and 90 days after planting on the protein content of the grain of nine varieties of wheat. All of the varieties yielded wheat of higher protein contents when nitrogen was applied 90 days after planting than when no nitrogen was applied. When nitrogen was applied at the time of planting and 30 days thereafter some varieties showed increased protein content and others a decreased content of protein in the wheat. He found that there was a relation between the extent of increase in vegetative growth and the percentage of protein in the grain. He concluded in part "that the supply of nitrogen available for the quantity of grain that any state of vegetative development may induce determines the protein content of any sample of wheat."

It is evident from these results that the application of top dressings of nitrogenous fertilizers may increase, decrease, or have no effect on the percentage of protein of the wheat. Such responses are to be expected if the relative supply of carbohydrates and nitrogenous compounds available for translocation into the developing kernel during the period from blossoming to desiccation determines the percentage of protein in the wheat kernel. Applications of nitrogen during the early periods of growth will tend to increase the degree of vegetative development of the plant. The increased size of the plant will offer increased opportunity for the synthesis of carbohydrates and may produce a larger number of heads due to increased tillering. Both of these factors may result in conditions favoring a larger yield of wheat without an increase in the percentage of protein or at times even in a decrease in percentage of protein. If sufficient nitrogen is applied so that more is present than is used in the extra vegetative extension it is

possible for the early applications to increase the protein content of the grain. On the other hand, applications of nitrogen at periods close to the heading time should increase the amount of available nitrogenous materials in proportion to the available carbohydrates and result in higher protein wheats.

Effect of Phosphorus and Potash Fertilizers

The relative supply of other necessary mineral nutrients such as phosphorus and potassium that are available to the plant may also affect the percentage of protein in the wheat. Ames (1910) has studied the effect on the composition of wheat of various fertilizer combinations applied on the fertility plots at the Ohio Agricultural Experiment Station at Wooster, Ohio. These plots were fertilized with different amounts and combinations of nitrogen, phosphorous, and potash. On the plots fertilized with nitrogen the maximum variation in protein content due to the season was 3.42 %, on the unfertilized plot it was 3.21 %. The maximum difference due to the application of fertilizer in any one season was 1.71 %. Later Ames, Boltz, and Stenius (1912), and Ames and Boltz (1917) continuing these studies found that the application of nitrogen alone or nitrogen and potash increased the percentage of protein in the wheat while the application of phosphorus decreased it. The percentages of carbohydrates were always in inverse relation to the percentages of protein.

In some studies relating to the effect of fertilizer treatment on rust development on wheat² at the Purdue University Agricultural Experiment Station, samples of wheat were available from plots receiving different fertilizer treatments. Analyses were made of these samples. The plots were grown in three different points in the state representing three quite different types of soil. Four pure varieties of wheat, Kanred, Iobred, Kawvale, and Purkoff were used. The response of all varieties to the different fertilizer treatments was very similar. Nitrogenous fertilizers increased the protein content of the wheat in inverse relation to their effect in increasing the yield. In one case the application of a double portion of nitrogen resulted in no increase in yield above that obtained with a single portion of nitrogen but increased the protein content of the wheat from 13.6 % to 16.8 %. Phosphorus applied alone and with nitrogen or potash reduced the percentage of protein in the wheat.

Murphy (1930) has carried out an extensive fertilizer experiment with wheat based on the triangular system. The fertilizers used were nitrate of soda, kainite, and superphosphate, the total application of fertilizer being 300 pounds per acre. He found that the protein con-

² K. D. Doak, Ph.D. Thesis, Purdue University, 1931.

tent of the wheat increased with the amount of nitrogen in the fertilizer. Phosphorus either alone or in combination with nitrogen or with potash decreased the percentage of protein in the wheat.

These results show very definitely that the amount of available mineral nutrients such as phosphorus and potassium as well as nitrogen may affect the percentage of protein in the wheat. In general, their effect in this regard seems to be related to their effect on the yield of wheat. This result is to be expected if the protein content of the wheat is determined by the relative amounts of carbohydrates and nitrogen available to the developing wheat kernel from the period of blossoming to that of desiccation. If applications of phosphorus and potash increase the size of the plant and the yield of the wheat, the amount of carbohydrates in relation to nitrogenous materials available for the developing kernel should be higher resulting in a lower protein content of the wheat.

Effect of Nitrogen on Quality

There is abundant evidence to show that the protein content of both hard and soft wheats may be increased materially by the application of nitrogenous fertilizers. Recently due to the decreased cost of nitrogenous fertilizers much interest has developed in the use of nitrogen salts for top dressing of wheat. When the application is made early in the spring increase in yield is usually largest and the increase in protein content is less marked. Although the practical use of nitrogenous salts for top dressing will be governed largely by the yield increases, their general use will doubtless result in increasing the protein content of the grain. This may ultimately have an important effect on the quality of the wheat. In the case of hard wheats, higher protein, if of good quality, is often desired. However, in the case of soft wheats used largely for baking biscuits, cakes, and crackers, and increase in the protein content may be detrimental.

Headden (1915, 1916) found that the presence of yellow or white, mealy or half mealy, or spotted kernels in wheat known as "yellow-berry" may be decreased or entirely prevented by applications of sufficient quantities of available nitrogen while the production of so-called "hard" wheat with small, flinty, translucent, dark-colored berries is increased. Potassium fertilizers increased the amount of "yellow-berry" while phosphatic fertilizers had no appreciable effect.

Davidson and Shollenberger (1926) found that flour from high protein wheat resulting from the application of sodium nitrate at heading time produced bread of superior qualities, while Gericke (1927) obtained poorer quality of bread in some cases. He states that "... it does not appear improbable that the poorness of some of the grain

high in total nitrogen was in part due to the over-feeding of the plants; . . . " Little is known regarding the quality of the protein in these high nitrogen wheats obtained by fertilization with nitrogenous salts. Gericke (1927) suggests that the non-protein nitrogen may be higher or that the amount of gliadin and glutenin may be lower in the high protein wheats of poor quality. The effect of phosphatic and potash fertilizers in lowering the protein content has been pointed out previously. It is possible that the use of liberal amounts of phosphates and potash in conjunction with the nitrogen may improve the quality of the wheat. Although climatic factors are doubtless dominant in influencing the composition of wheat, the use of fertilizer offers a practical means of influencing quality.

Summary

It is suggested that the protein content of wheat is dependent upon the relative amounts of carbohydrates and nitrogenous compounds made available to the developing grains during the period of translocation.

The effects of long periods of maturity, abundant moisture and rainfall, low temperature, etc., during the period of maturation in producing a low protein wheat is due to their effect in favoring a relatively greater abundance of carbohydrates in relation to the nitrogenous compounds.

The effects of short periods of maturity, warm weather, and moderate rainfall during the period of maturation in producing high protein wheat is due to their effect in favoring a relatively greater abundance of nitrogenous material in relation to the carbohydrates.

The applications of nitrogenous fertilizers may either decrease or increase the protein content of wheat or have no effect on the protein content depending upon their effect on the relative amount of carbohydrates and nitrogen available for the developing kernels during the period of translocation.

The application of phosphatic and potash fertilizers may affect the protein content of the grain by influencing the amount of available carbohydrate and nitrogenous compounds available for the developing kernel. In general, the application of phosphorus or phosphorus and potash decreases the protein content of the wheat.

Climatic factors are probably the most important in determining the composition of wheat.

The use of fertilizers offers a practical means of influencing the quality of wheat.

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REPORT OF THE CEREAL SECTION OF THE ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS

J. A. LECLERC, GENERAL REFEREE, 1931

Bureau of Chemistry and Soils, U. S. Department of Agriculture,
Washington, D. C.

(Received for publication December 18, 1931)

With an attendance of 45, many of whom are members of the American Association of Cereal Chemists, and the presentation of 11 live papers on various methods of analyses, the 1931 meeting of the Association of Official Agricultural Chemists was the most interesting and stimulating held in many years. For the first time in the history of the Association, the cereal chemists met separately, only those especially interested in cereal subjects being present. This year's meeting was so successful that the same plan will be continued in the future. For 1932 it is planned to have, besides the regular reports on the various methods, a number of addresses by outstanding cereal chemists on subjects or problems of general interest. Such meetings should prove of added interest to the members of the American Association of Cereal Chemists. It is hoped to make the November meeting of the Association of Official Agricultural Chemists serve as a fall meeting of the American Association of Cereal Chemists.

A greater degree of collaboration is aimed at between the cereal chemists of the Association of Official Agricultural Chemists and members of the American Association of Cereal Chemists. In fact it is planned to call upon members of the American Association of Cereal Chemists to assist in the collaborative work of the various referees.

A summary of the reports with titles as prepared and read by the Associate Referees follows:

1. THE ASH OF FLOUR, by *D. A. Coleman*. Wheat flour was ashed at 450°, 550°, 650°, and 750° C. The results obtained were essentially the same although in all cases, flour ashed at 650° C. or higher fuses. Even at these higher temperatures, however, the results are satisfactory if care be taken to avoid occlusion of carbon.

Flour was also ashed in a stream of oxygen, the results agreeing with the official method. The use of oxygen, however, caused a saving of 2 to 3 hours in time of ashing.

A study was made of weighing the ash direct and while the results

agreed with the indirect method of weighing, i.e., with the official method, there was no appreciable saving in time.

2. REPORT ON EXPERIMENTAL BAKING TEST, by *C. C. Fifield*. The study included a comparison of the results obtained by baking a "pup" loaf obtained by doughing 100 grams and 200 grams of flour respectively. In the latter case the dough-mass was divided into two equal parts. The method used was essentially that of Werner, modified by Blish. In general, the results compared quite favorably.

3. THE HYDROGEN-ION CONCENTRATION OF FLOUR AND BAKING PRODUCTS, by *Emily Grewe*. This report covered a review of the literature on this subject to date.

4. REPORT ON DIASTATIC VALUE OF FLOUR, by *M. J. Blish*. (Read by H. C. Gore.) This paper included an elaborate study of the Rumsey method for the determination of the diastatic activity of flour, modifying the temperature of digestion and the pH of the solution. The sugar determinations were made colorimetrically. The method has been so perfected by the Associate Referee that it will, next year, be subjected to collaborative study.

5. STARCH IN FLOUR, by *Llewelyn Jones*. (Read by C. B. Morison.) Collaborative work was carried on with the Rask method and the diastase-acid hydrolysis method as modified by Hartmann and Hillig. The results were not satisfactory.

6. FLOUR BLEACHING, by *Dorothy B. Scott*. The work which formed the basis of the report was collaborative in character and consisted in analyzing flours which had been treated with Beta Chloral and Agene, respectively. Some progress was made in the testing of flour bleached with Novadelox. The work will be continued again next year.

7. CO₂ IN SELF-RISING FLOUR, by *L. D. Whiting*. (Read by M. R. Coe.) Three samples of self-rising flour were submitted to 8 collaborators for determination of total CO₂. The results from every collaborator, except one, although somewhat lower than the theoretical, were considered very satisfactory. The flours contained 0.746%, 0.867%, and 0.982% CO₂, respectively. The collaborators' average findings were 0.712%, 0.819%, and 0.921%.

8. SAMPLING AND DETERMINATION OF MOISTURE IN BAKED PRODUCTS AND ALIMENTARY PASTE, by *L. H. Bailey*. The report showed that the method of heating these food products in an air oven for one hour at 130° C. was satisfactory for bread and macaroni products, but that further work would be necessary in the case of cake.

9. LIPOIDS AND LIPOID P₂O₅, by *J. H. Bornmann*. (Read by L. H. Bailey.) The work, collaborative in nature, consisted in a comparative study of the tentative method with the CHCl₃-alcohol

modification for the determination of lipoids in alimentary paste and baked products. The results were not satisfactory and the work will, with modification, be repeated next year.

10. RYE FLOUR IN RYE BREAD, by *M. R. Coe*. This, the first report ever presented to the Association on this subject, consisted chiefly in a review of the literature. Some laboratory work was done but, as the report stated, without success.

11. BAKING POWDER AND BAKING CHEMICALS, by *W. C. Geagley*. This report chiefly related to contemplated work.

No reports were submitted by the Associate Referees on the following subjects: (a) "A Comparison of Foreign and Domestic Methods of Chemical Analysis of Flour." (b) "Crude Fiber in Baked Products and Macaroni." (c) "Milk Solids in Milk Bread." (d) "Unsaponifiable Matter in Flour, Alimentary Paste, and Baked Products."

Recommendations of Referee

The Referee recommended that the following methods be further studied:

- (a) Determination of starch in flour.
- (b) Determination of chlorine in flour.
- (c) Detection of benzoyl and other peroxides.
- (d) Unsaponifiable matter in flour, and baked products and macaroni.
- (e) Determination of ash in flour, baked products and macaroni.
- (f) Determination of hydrogen-ion concentration colorimetrically in flour and baked products.
- (g) Determination of diastatic activity in flour.
- (h) Comparison of foreign and domestic methods applicable to flour, baked products, and macaroni.
- (i) Determination of water soluble protein nitrogen precipitable by 40% alcohol in flour and macaroni.
- (j) Determination of CO_2 in self-rising flour.
- (k) Determination of color in flour.
- (l) Determination of milk solids in milk bread.
- (m) Determination of rye in rye-wheat mixtures and in rye bread.
- (n) Determination of chlorides in baked products (official first action).
- (o) Method for making a standard baking test.
- (p) Determination of H_2O in cake and alimentary products.
- (q) Determination of fat in bread and macaroni by acid hydrolysis (official first action).
- (r) Determination of lipoids in baked products and macaroni.
- (s) Determination of lipoid P_2O_5 in baked products and macaroni.

- (t) Determination of crude fiber in baked products and macaroni.
- (u) Preparation of sample of macaroni for analysis.
- (v) Determination of total P_2O_5 in macaroni products.

Methods Approved by the Association

The following methods were approved by the Association.

(a) That for the purpose of making the usual chemical determination in bread, either $\frac{1}{2}$ of the loaf or the whole loaf be taken as a sample (official final action).

(b) That the tentative (vacuum oven) method for determining water in air-dry bread be made official (first action).

A NOTE ON THE SEPARATION OF DIASTATIC ACTIVITY FROM STRENGTH IN BAKING TESTS

L. ELION

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(Received for publication November 18, 1931)

Jørgensen, in a recent Danish publication (1931) and in a paper in this journal (1931a), made a valuable contribution to the problem of experimental baking tests. In view of the work of Humphries and others, which indicates that diastatic activity of a flour is independent of its strength, Jørgensen was surprised to find that many of the baking test methods described in the literature were of such a nature that the diastatic power of the flour is not separated at all from strength, and that, consequently, the volume of the test loaf is often the function of the gassing power of the flour as well as of its strength.

Jørgensen emphasizes the fact that in order to exclude the influence of the diastatic quality, there must not be a shortage, but, on the contrary, an excess of fermentable sugar at every moment during the dough-time and he describes how it is possible to decide experimentally whether a given formula for baking tests satisfies this requirement.

In a discussion of the results of his investigation, Jørgensen comments on a paper, published by the author (1928), on the quantity of yeast to be used in baking tests. Jørgensen stated: "Elion shows in a very clear manner, that under certain circumstances more carbon dioxide is developed from dough to which sugar has been added than from corresponding doughs to which no sugar was added. However, from the work of Elion, one can not but get the impression that Elion finds that the addition of sugar to the A. A. C. C. dough is somewhat unsafe as important flour properties such as its diastatic power might

be obscured by the addition of sugar. In direct contrast to Elion, the author (Jørgensen) is of the opinion that it is a good feature of an experimental baking method that the diastatic activity is obscured. In fact, following Humphries' principle, diastatic activity must not influence the baking results at all. The author's (Jørgensen's) objection to the A. A. C. C. Basic Method is quite opposite to Elion's. The author (Jørgensen) criticizes the A. A. C. C. Basic Method because in spite of the addition of sugar, this method does not guarantee that the diastatic activity will not influence the baking result."

Since the present matter is of much practical interest, the author takes this opportunity to state that he agrees entirely with Jørgensen's opinion that, *when comparing the strengths of different flours*, care should be taken to use a baking method in which the diastatic activity is obscured, and in which the possibility of shortage of fermentable sugar is precluded. Nevertheless, in his paper in question (1928), the author (Elion) has drawn attention to the drawback that important flour properties may be obscured if sugar is added *in every baking test*. It is quite obvious that the estimation of the strength of a flour is undoubtedly an important objective of the baking test, but it is by no means the only one. It is a well known fact that baking tests are not used exclusively for flour testing. Indeed, they are of great utility in the study of the properties and the action of different baking agents. It may suffice, in this connection, to refer to baking agents containing diastase, in order to set forth the advantage of a formula which does not obscure the diastatic power of the flour by the addition of sugar.

As to the purpose of the baking test in the examination of flour, the author is of the opinion that this test can not be limited to a procedure for estimating strength, in the proper sense. With all of its practical difficulties, the baking test can also furnish valuable information with regard to strength and many other flour properties, which together constitute baking quality, thus making it possible to foretell what will happen when the flour is used for bread making on a larger scale. To be of service for this purpose, however, the baking test has to meet the requirement of imitating, as much as possible, practical conditions. Hence, it follows that if no sugar is used in commercial baking, as, for instance, in European countries, it will not be advisable to prescribe its addition in *such* baking tests, nor to obscure the diastatic power by other means. As already set forth by the author (1928), the quantity of yeast too has to be attuned to the industrial formula, since the use of a greater percentage may increase the influence of diastase in the laboratory test in an undesirable way.

It is the author's view, therefore, that Jørgensen has gone too far in stating that diastatic activity should not influence the results of the

baking test at all, and to further emphasize this point we are disposed to discount the value of the results of several excellent methods (all the methods based upon Rumsey's fundamental principle) for determining the diastatic power. It may be true that Rumsey's autolytic method is a reliable one and very useful in comparing the diastatic properties of different flours, but the author can not overlook the difference in conditions between such a test method and actual bread making. Moreover, other factors than diastatic activity are influencing the question whether, and to what extent, a shortage of sugar will occur during the rising of the dough; factors which are left out of account in Runsey's procedure.

It would be erroneous to deduce from the foregoing that the necessity of eliminating the influence of the diastatic properties only exists if a baking test has for its object to determine the strength of a flour. That is not the case, and the author would conclude by stating that, as a general rule, the principle, raised by Jørgensen, can not be neglected whenever information has to be procured about a property, which may be obscured in consequence of the magnitude of the action, exerted by the diastase on the fermentation process. Such a property is, for example, the rising power of the yeast, which, as is well known, may be tested by making bread. Certainly, it is not necessary to explain that a shortage of fermentable sugar in such a test will bring on misleading results. Nevertheless, it is quite certain that this fact is but insufficiently taken into account in the art.

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1931 Om adskillelse af diastatisk kraft og egentlig bageevne ved udførelsen af bageforsøg. *Den Danske Møller*, August 1931.
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BOOK REVIEW

Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists. Third Edition, 1930. Published by the A. O. A. C., Box 290, Penna. Ave. Station, Washington, D. C. Price \$5.00 postpaid United States, its possessions, and Canada; \$5.50 net to all other countries.

The third (1930) edition of the Book of Methods of the A. O. A. C. stands as a tribute to this Association for the vast amount of research undertaken and carried forward in an effort to develop, perfect, and standardize methods for the analysis of agricultural products.

The organization of the book is similar to that of the first and second editions, but includes some noteworthy changes. For the purpose of bringing together closely related subjects, the subject matter has been broadly grouped into two divisions—non-food and foods. The first division includes chapters on soils, fertilizers, liming materials, etc., while the second division is devoted entirely to the analyses of foods and feeding stuffs. This latter division will be of more interest to the cereal chemist. To facilitate ease of reference, and permit the book to be more readily used as a laboratory guide, the subject matter has been arranged in alphabetical order. Methods on related subjects have been combined and several independent chapters of former editions have been consolidated.

For the first time, methods are described for the analysis of caustic poisons, paints, eggs and egg products, and for the determination of the radio-activity of foods and drugs.

As was the case in former editions, the methods presented are classified as official and tentative. Mention is made, however, of those tentative methods which have received first action as official methods. (Second favorable action by the Association is necessary before a method is finally adopted as official.)

The book as organized is composed of 495 pages of text, 68 pages of reference tables, and a worthwhile index. The subject matter is organized in chapter form, of which there are 32.

Chapter XX, "Cereal Foods," covers approximately twice as much space in this edition as in the 1925 edition. Methods are described for the analysis of wheat flour, baked cereal products, and alimentary pastes. With respect to the analysis of wheat flour in addition to the directions which are given for sampling, directions are given for the determination of moisture, ash, crude fat, crude fiber, acidity of water extract, hydrogen-ion concentration, sugars, protein, 70 per cent alcohol soluble protein, proteins soluble in 5 per cent K_2SO_4 , globulin, albumin and amino nitrogen, glutenin, crude gluten, water soluble nitrogen precipitated by 40 per cent alcohol, lipoids and lipid phosphoric acid, unsaponifiable residue, cold water extract, starch, chlorine, nitrite nitrogen, and gasoline color value.

With respect to baked cereal products, the following methods for the analysis of bread are described: Preparation of sample, moisture in entire loaf, moisture in air-dry sample, ash, chlorides in ash, protein fat, and crude fiber.

Of signal importance to the cereal chemist is the inclusion in this edition of the A. A. C. Experimental Baking Test as a tentative method.

In connection with the analysis of alimentary pastes, directions are given for preparing the sample for analysis, and for the determination of moisture, ash, chlorides in ash as $NaCl$, fat, crude fiber, protein, water soluble nitrogen not precipitable by 40 per cent alcohol, lipid and lipid phosphoric acid, for the detection and determination of added color, for the detection of the presence of whole egg or commercial yolk solids, and for the determination of egg solids.

In addition to the methods cited in Chapter XX, the flour mill chemist and the chemist interested in the manufacture of self-rising flour, will be interested in Chapter XV, "Baking Powders and Baking Powder Chemicals," and Chapter XXVII, "Grain and Stock Feeds." New methods in Chapter XXVII relate to the determination of moisture, to the determination of salt, oathulls in oats, and calcium oxide in mineral feeds.

For the bakery chemist, the chapters relating to the analysis of baking powders and baking powder chemicals, cacao bean and its products, coloring matter in foods, dairy products, egg and egg products, flavoring extracts, spices and other condiments, sugars and sugar products, and water, should be of consummate interest.

The book reflects, in every chapter, the great amount of careful work which was done by the Editorial Committee in the compilation and organization of the text.

D. A. COLEMAN.

INTERNATIONAL BREAD-MAKING CONGRESS AND EXHIBITIONS TO BE HELD IN ITALY, JUNE, 1932

An important international bread-making congress and exhibitions are to be held in Italy during June, 1932. With the approval of the Italian Government the following manifestations will be held:

In Rome

- (a) International Scientific and Technical Congress (from June 20 to 24, 1932).
- (b) International Exhibition of all types of bread made throughout the world (from June 20 to 30, 1932).

In Bologna

- (a) International Exhibition of Machinery, Equipment, and Accessories for Bakeries (from June 15 to July 15, 1932).
- (b) National Exhibition of Machinery, Equipment, and Accessories for Paste making (from June 15 to July 15, 1932).
- (c) National Bread-making Competition and Exhibition of the qualities of bread made in all the Italian Provinces (from June 15 to 30, 1932).

Machinery manufacturers, technical experts, scientists, and master-bakers throughout the world are invited to attend and to participate in this congress and exposition.

Information can be obtained from:

Ing. Arnaldo Luraschi,
President, National Fascist Federation of Master-bakers and
Allied Trades,
2 Piazza Sonnino,
Rome, Italy.

or from:

"La Panificazione,"
24 Via Sttembrini,
Milan, Italy.